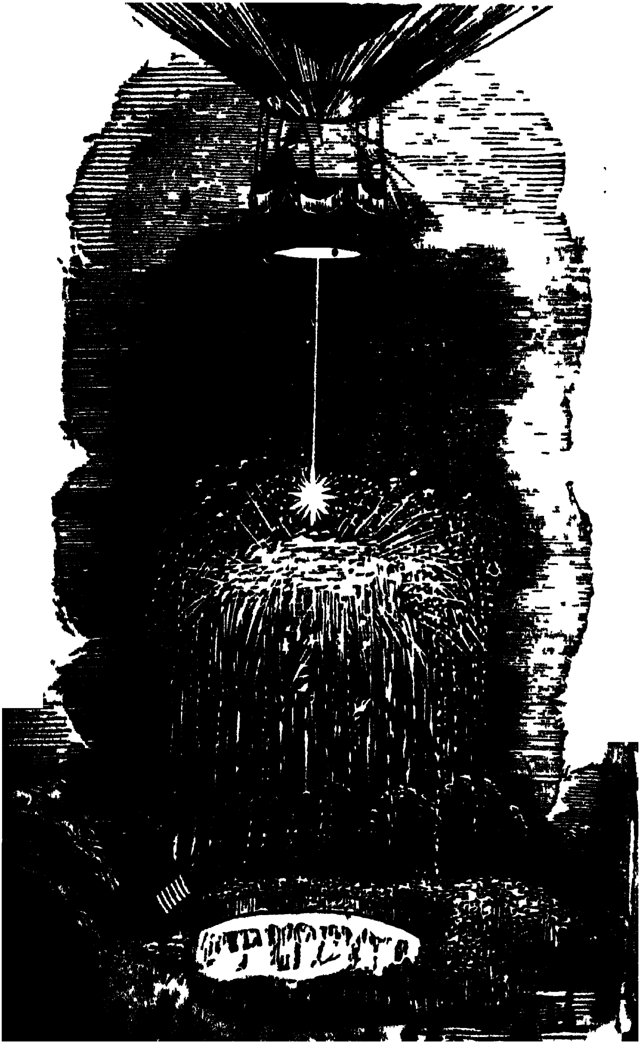
THE

PANORAMA OF SCIENCE.



THE

PANORAMA OF SCIENCE;

OR,

A GUIDE TO KNOWLEDGE.

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PREFACE.

The desire of obtaining knowledge is one of the most natural, and, at the same time, most ennobling attributes of the human mind, for it is impossible, whatever may be our station in life, to walk through the world without noticing facts of the highest interest, which cannot be duly appreciated unless properly understood.

The Panorama of Science is intended, like a guide-book to strangers, to lead our readers through the most agreeable paths to knowledge, and explain in the most simple manner the Principles of Science. No scholastic difficulties will be allowed to impede our progress; for there is now no necessity to affect, like the priests of old, an air of mystery in elucidating the artless means which nature takes to accomplish many of her most important and beautiful operations: indeed, truth disdains all artifices; she does not love to appear masqueraded in the costume of quaint and hyperbolical devices; her ways are ways of the utmost simplicity, and may be readily understood by every individual desirous of acquiring information. This information we will now lay before the reader, excluding, or explaining, all scientific terms; and it is hoped that this will appear a "Panorama" more than in name.

G. G.

Liverpool, May, 1849.

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THE PANORAMA OF SCIENCE.

INTRODUCTION.

Scientific knowledge has often been neglected from an idea that it can only be attained by individuals who previously possess considerable information. There cannot possibly exist a greater mistake; for nature is so simple in all her operations, that they can be rendered as intelligible to the mind of the humble mechanic or unlettered peasant, as to that of the haughty peer or the most learned philosopher. It is certainly true, that in former times, partly from ignorance or the defect of the English language, and partly from an ignoble wish to fetter the progress of the human mind, the most simple truths were studiously obscured; but the curious signs and figures—the harsh and disjointed phraseology—the crude and complicated technical terms which were then in general use, have now been done away with, and the path to the Temple of Science is at the present day open and easy of access to all.

In this age of intellectual excitement many means have been contrived to extend the blessings of education; and schools of art have been instituted, and popular lectures judiciously delivered, with the view of communicating,

in the most easy and familiar manner, those principles of science which explain the various phenomena of nature, and the different processes of art by which we can supply the necessaries and the luxuries of life. But it is now our intention in publishing this volume, to *bring home to every fireside in the kingdom*, that species of information, which has hitherto been confined to schools and lecture rooms, or published in an expensive or too elaborate form for general use. To obviate every difficulty, therefore, and to render the scientific subjects of which we are about to treat, adapted to the capacity of even the most illiterate of readers, the most perfectly simple style of language will be used in the composition of the following articles.

Science admits of two general divisions; the first comprehending an investigation into the nature and operations of our own minds; the second, into the various properties and conditions of matter, or the objects which we perceive in the external world. It is by a strict examination into these that we become acquainted with the laws of nature, without some acquaintance with which we must be continually passing over many objects and events unnoticed, that would otherwise excite the greatest possible interest and admiration. Nor is this all; for when any event does occur of so uncommon and striking a kind as to attract our attention, and so to awaken our ignorance, if we are unable to explain it on fixed principles, we must fall back upon the suggestions of fancy, which, as every person has found, lead to the most absurd and extravagant superstitions. Thunder and lightning, comets, meteors, northern lights, rainbows, and indeed every phenomenon of nature has in its turn, excited those superstitious feelings which appear natural to man while in a state of ignorance; but happy are we that such is not the condition of the working men of the nineteenth century—the schoolmaster is abroad, and a *cheap* press has wrought miracles. But a few examples will not be out of place here to show the advantages we enjoy over what our forefathers enjoyed.

In ancient times thunder and lightning were regarded as occurrences beyond the common course of nature. Under the Mosaical dispensation, the Jews were accus-

tomed to open the doors and windows of their dwellings during a thunder storm, in the expectation of the promised Messiah making his appearance amidst this war of the elements. The Roman Catholics, in many districts of Germany, toll the bells of the churches during the continuance of a thunder-storm; and in Athens, when a person was struck dead by lightning, the spot on which the accident occurred was enclosed, and an altar raised for the people offering up their sacrifices to their gods. The superstitions of the ignorant which gave rise to such customs, have, from the rapid advancement in our own days of the knowledge of science, not only been dispelled, but we have contrived, by a very simple expedient, to rob the cloud of its lightning, and to protect our houses and churches from its disastrous effects. Comets have also been, from a very early period, regarded as unnatural events, which appeared in the heavens to predict the most dismal calamities, such as wars and pestilence, the dethronement and death of kings, and the destruction of empires. By referring to the history of Rome we will observe the undue importance which was attached to the comet that appeared a short time previous to the Augustan war, and to that which attended the battle of Pharsalia; neither has Josephus, the celebrated Jewish historian, been sparing of them at the destruction of Jerusalem. During those days of ignorance and superstition comets were merely regarded as flaming meteors; but thanks to the progress of discovery, our astronomers are now enabled to examine their nature more minutely—to point out the orbit they describe—and to foretell with certainty the periods of their return. Meteors, which occur so much more frequently than comets, have also aroused the apprehension of the vulgar, who have fancied them to bear away the spirits of the departed, and to be the sure forerunners of death. "The account," says Mr. M'Pherson, "given to this day by the ignorant, is very poetical. The ghost comes mounted on a meteor, and surrounds twice or thrice the house destined for the person to die in, and then goes along the road through which the burial is to pass, shrieking at intervals; at last the meteor and the ghost disappear above the burial place." Northern lights have also given rise to many

conjectures and prophecies. If of a pale colour, they were supposed to be the precursors of famine; if of a brilliant red appearance, to be ominous of pestilence and war. The rainbow even, which "compasseth the heaven about with a glorious circle," has been the parent of numerous fanciful notions. The superstition of the Athenians caused altars to be raised for its worship; and even to the colours it exhibits were assigned a mysterious interpretation, during the earlier ages of Christianity. The red and green colours were considered to be significant of the destruction of the world by fire and water; while in the other colours were recognised typical allusions to the mysteries of baptism and the holy sacrament of the supper. These, and many other false notions we could point out, shew, that without some knowledge of the elementary principles of science, we not only fail to observe and appreciate, but are apt to place an absurd and mischievous interpretation on the most interesting and beautiful phenomena of nature.

By the aid of scientific principles, derived from the observation of a few facts of the most simple kind, and which are capable of immediate proof, the weakest disciple of science has it in his power to explain the properties and effects of light—the sources, operations, and numerous applications of heat—the composition of air and water, and the various kinds of earths, minerals, metals, and other substances of which this globe we inhabit is composed. Besides all these, there are many phenomena of frequent occurrence which claim peculiar attention; the varied and frequently beautiful colours that are often observed reflected along the sky—the formation and varieties of clouds—the condensation and fall of snow, hail, rain, and dew—the motions of the air, sea and land breezes, trade-winds, whirlwinds, the hurricane, the tornado, and the simoon—the various appearances which prognosticate change of weather—the transparency, the glowing tints and depths of the ocean, with the motion of its waves, its tides, its currents, and its whirlpools—the lakes, rivers, and springs, which so beautifully diversify the face of nature; the terrible convulsions which, under the form of earthquakes, lay the proudest cities in the dust, and overwhelm with fear the

heart of man—these, and many other wonders of creation, are well calculated to excite, even in the most heartless mind a spirit of inquiry, which, once aroused, will go along upon its path rejoicing, fully conscious that at every step it is gathering power and enlarging the boundaries of human happiness. All mankind, natural historians, moralists, poets—are accustomed to speak of the surpassing beauties of nature; but these cannot be felt nor sufficiently appreciated without being properly understood; therefore this is one of the strongest inducements for us to cultivate such knowledge—to apply ourselves to obtain a clear perception of the globe we inhabit—for whatever may be the sphere of life in which we are destined to move—whatever the duties we may be called upon to perform, or the cares and anxieties that may oppress us, there are times when we escape from these into the free open air, to wander perhaps through the green fields or along the sea shore, and then the mind so endowed carries along with it a talisman, by which it can at all times command the most interesting subjects for its contemplation. But besides the foregoing inquiries, which relate principally to what is termed inorganic matter, when we have examined the irregularities of the earth's surface, its mountains and its vallies—its hills and its plains—its stupendous rocks and its level shores, it will remain for us to to consider the numerous tribes of organic beings which in these different regions find their appropriate abode. We shall find that the vegetable creation alone opens up to us a world which first bewilders us with the multitude of its wonders and beauties, and then charms us into meditation. Every plant, from the humble moss clinging to the barren rock, to the majestic oak of the umbrageous forest—from the despised weed on which we disdainfully trample, to the beautiful flower which it is our delight to cultivate, are under the influence of the same unalterable laws—they all require light, heat, air, and moisture; they all possess a living principle, and require a certain quantity and kind of nourishment which is distilled into sap, and converted into different kinds of matter, for the leaves, flowers and fruit; they have all the faculty of reproduction, whereby the same species is continued, and they all

grow, attain maturity, and then die, and their decayed remains, even as human dust, then contribute to the formation of the soil, which is always by such means in the course of renewal. The seeds and fruits of some of these plants, by various processes of art are converted into food, examples of which we have in the numerous kinds of grain now cultivated in Europe; others again which supply us with the means of clothing, instances of which we reçognize in the hemp, flax, and cotton plants; others produce valuable medicinal substances, by which we are enabled to lessen and often entirely subdue the sufferings and progress of disease; besides all which, it is almost unnecessary to add that timber of different kinds forms a most important article of commerce, seeing it is applied to so many purposes of life.

From all this we perceive that the vegetable kingdom not only adorns the world with verdant beauty, but that all its productions, its grasses, herbs, shrubs, and trees, are adapted to supply the various wants of the great human family. But it is not man alone that derives support and enjoyment from that source; the plants that grow beside rivers, the shrubs that beautify rocks, the extensive forests formed by the grouping together of trees,—all afford nourishment and protection to thousands of living beings. Here myriads of insects that have hitherto escaped the observation of the naturalist, and birds whose melodious warblings are unrivalled by human art, enjoy their liberty; there, also, secure from the dominion of man, animals, in their wild and undomesticated state, find shelter. As the principle of life which exists in plants does not lead to the obvious manifestation of any sentient or thinking principle, they have been placed at the bottom of the scale of organized beings, ascending from which the numerous living beings that inhabit the air, the water, and the earth, and which exhibit a regular advancing scale, from the most simple to the most complicated structures, engage our attention and our interest. Certain general laws we find govern all these—they all require light, heat, air, and food—they all have the power of multiplying their individual and distinct races—they all grow and enjoy the power of locomotion—they have all senses which warn them of

the approach of danger, and enable them to select the most proper substances for their support—they have all their appropriate residences, some being the inhabitants of cold, others of hot climates, some being destined to live in the bosoms of vallies, others on the heights of mountains—they have the habits which are connected with certain peculiarities visible in the form of their bodies—they all endure only a temporary existence, some of them living only a few minutes, others for centuries; and finally, like the plants already noticed, the remains of their decaying bodies contribute to the formation of the earth on which we tread. Finding himself perplexed, by the immense number of these animated beings, the naturalist has arranged them according to their various forms and habits into certain general divisions, and these again he has subdivided into particular classes, genera, species, and varieties. At the head of these, pre-eminently distinguished by the faculty of speech, and the powers of his mind, we find man, whose knowledge, when tempered with humanity, teaches him humility, forbearance, and gentleness to all living things. In his uncivilized state man is perhaps the most abject and helpless creature that moves on the face of the earth; nor is it until the light of reason dawns upon his soul that he can understand how to supply his numerous necessities and comforts. Naked, unarmed, exposed to all the inclemencies of the weather, he seeks only to redress his immediate physical wants. His hunger he appeases by eating the fruits of the trees, or the roots of herbs—his thirst he quenches at the river's brink, and his abode is in the depths of otherwise unfrequented forests. In this state he has no language to explain his ideas; but let us turn from a picture so humiliating to human vanity, and contemplate man in his more civilized condition, enjoying not only all the comforts, but likewise the luxuries conferred on him by the progress of the arts and sciences. Imperial Rome, formerly the mistress of the world, originally consisted only of a few mud hovels irregularly scattered, and we are informed by Vitruvius, that even in his time, the Temple of Romulus, was thatched with straw for its preservation. Such was the origin of that proud city; and this is only an emblem of the significant

changes, improvements, and contributions to happiness that have been, and will be effected, by the progress of the human mind.

Great Britain itself, which has held so commanding an attitude among surrounding nations, has also risen from as humble an origin; and to what can her glory and prosperity be attributed? Undoubtedly to the advanced state of the arts and sciences; it is this which led to her conquests both by land and sea; and it this which now forms the broad and firm basis of her commerce. The application of the principles of science to her various manufactures has brought many of them to a state of the most wonderful perfection. When we consider, therefore, that the knowledge of the principles of chemistry will enable us to understand the most interesting processes of art, no one will deny that it is a most desirable acquisition, more especially as it requires but little sacrifice of time and no great application to study. By referring to the History of Great Britain we will learn that previous to the eight century glass was an article unknown, and that the windows of houses, and even of cathedral churches, admitted light through fine linen cloths, or lattices of wood; but now, by the union of potash and a certain kind of sea sand, and the application of heat, glass is formed, which supplies us with the means of enjoying light in our habitations, while at the same time it excludes the inclemency of the weather; and the manufacture of glass at the present day forms an important branch of our trade. The arts of bleaching, dyeing, and tanning, are likewise chemical operations, which may be understood with little difficulty. The process of bleaching is one of great antiquity; for we are credibly informed that lime was used in bleaching 300 years before Christ. Here the bleacher has been indebted to the progress of science, as without knowing the elementary principles of which, it is not possible to understand the action that takes place in this process. In dyeing, not a colour can be imparted unless an affinity or attraction exists between the cloth and the dye; and if this is not present, recourse must be had to some other agent to form a bond of union between them. For example, if we dissolve some indigo in a little common vitriol, and dilute it largely with water, and then dip into

the solution a piece of silk, linen, or cotton, we shall find, on taking it out immediately, that the indigo combines with the cloth and gives it a blue colour; but if, in the place of indigo, we use cochineal, or madder, and immerse the cloth, we shall find that there is so slight an attraction between the colouring matter and the fibres of the cloth that it only receives a stain which may be removed by washing. In this case a mordaunt or basis, generally a preparation of iron or tin, is requisite to render the dye permanent. We hereby perceive that the process of dyeing depends on a chemical action, which admits of a very easy explanation. Tanning, likewise, can only be understood, by having recourse to the science of chemistry, which has taught us that, in the rind or bark of trees, more especially of the oak kind, a substance is found which may be made, by a very simple process, to combine with the skins of animals, so as to form leather. The mode of extracting metals, also, from their different ores, and the important art of agriculture, require a knowledge of chemical principles. Besides these, even the most simple culinary processes, daily going forward in our kitchens, proceed likewise on principles of chemistry, which every individual ought to understand. We are informed that Count Rumford, the distinguished philosopher, did not disdain to exercise the powers of his scientific mind in devising means to improve the art of cooking. He endeavoured to ascertain how the greatest quantity of nourishment could be obtained from food at the least possible expense; and so successful was he in his experiments, that, in one of his establishments at Munich, three women prepared a dinner for a thousand persons, and burned only ninepence worth of fuel. He proceeded so far in his improvements so as to economise all the heat of the smoke; and it was even believed, had he lived, that he would have cooked his own dinner with the smoke from his neighbour's chimney. Many more examples might be here brought forward to illustrate the universal application of the principles of science, but sufficient has been said to point out how much there is to delight as well as to interest the student as he advances along the path of useful knowledge. We may observe that the instruction which thus enables us to appreciate the beauties of nature, and qualifies us

to understand the various processes of art, should exercise the happiest and most beneficial effects on human character; for such meditations are every way calculated to elevate the thoughts, refine the feelings, enrich the imagination, and render us happier as we proceed on our journey through this world, and at the same time making us better fitted for the enjoyment of a glorious eternity.

LIGHT.

"In the beginning God created the heaven and the earth. And the earth was without form, and void, and darkness was upon the face of the deep: and the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light." The accomplishment of the divine command was immediate, and the sudden removal of the dismal darkness which was upon the face of the deep was instantaneously followed by the bright splendour of the sun. The transition presented over the whole appearance of the now illumined, face of the waters, must fill every thoughtful mind with a sense of power and sublimity which cannot be exceeded. We cannot feel surprised that this light, so unsullied in its nature, and so lovely in all its different effects, suddenly called into existence,—we cannot feel surprised, we repeat, that this light, which so freely scatters its blessings around us, should have attracted the attention of the most highly gifted and accomplished philosophers. Let us then enter on this interesting subject, and proceed to consider its nature and properties, and its influence on the animate and inanimate creation.

The sun, which has been worshipped as a visible God by many nations, is the most obvious source of light and heat; and every one is now, or ought to be aware, that it is the change of position which our earth, in its constant revolution, undergoes in its relation to that luminary, which causes and regulates the return and duration of day and night, and the succession and intensity of the different seasons. But the sun is not the only source of light; for was this the case we should be left during the period of night in the helplessness of darkness, than which nothing could be more dreadful. Instead of this, however, when the sun has sunk below the horizon, and the twilight which follows has faded away, the reflected light of the moon, and the light of innumerable stars, shed a soft and sparkling lustre through the

world. These heavenly bodies are the most obvious sources of natural light; but man, at a very early period, prompted by his necessities, contrived to procure both light and heat artificially, to accomplish which, he had recourse to several ingenious plans. It was observed, that when two bodies are pretty smartly rubbed against each other, both light and heat are obtained by the friction. The arctic Highlanders of Baffin's Bay obtain fire by rubbing two fish bones against each other. The Fuegians, an uncivilized race of people, inhabiting one of the coasts in the Southern Ocean, procure fire by rubbing a pyrite, or firestone, and a flinty stone together, and catching the sparks on a soft dry substance resembling moss, which is quickly ignited. The inhabitants of New Holland take two pieces of soft dry wood—the one a stick about eight inches long, the other a flat piece. The stick is shaped into a blunt point at one end, and pressed firmly against the piece of wood, holding it between both their hands, and turn it quickly round. By this method light and heat are obtained, in somewhat less than two minutes. It is for this reason necessary to grease the iron at the axis of carriage wheels, as otherwise from the friction, when the carriage is drawn swiftly along, as on railways they are apt to take fire—an accident which has frequently occurred. Friction, therefore, is one of the sources of artificial light. When one body is quickly struck against another, say a piece of flint against a piece of iron, light and heat are likewise produced. This is the method of obtaining light and heat by percussion; and it is well known that advantage is taken of it in the locks of guns and pistols. When fire has been thus produced, it is applied to an inflammable body, during the burning of which, a more or less bright light is emitted. Thus oil and tallow are inflammable substances, and by putting in either of these, a piece of cotton wick, on lighting which the oil or tallow rises through its threads and produces a steady flame. Many gases are likewise inflammable, and when mixed together in certain quantities, consume more or less rapidly.

Light is also produced by electricity, which is a very peculiar and subtle fluid, that seems to pervade in a greater or lesser degree all bodies, animate or inanimate. When this electric fluid has accumulated in any particular

region, it seeks to disperse or equalise itself, and in so doing, evolves itself, and becomes perceptible to our sight. This is the cause of lightning; and many are of opinion that it is likewise the cause of the aurora borealis, meteors, shooting stars, and other interesting phenomena in nature. Certain animals also have the power of generating a phosphorescent kind of matter, which gives out light, such as the glow-worm, the fire-fly of the West Indies, and some descriptions of fish. It is probable that sea water is capable of dissolving this luminous matter, which explains the reason why the waters of the ocean by night often appear shining when agitated. Such are the general sources of light. But the principal, and most constant of them all is undoubtedly the sun.

Naturally inquisitive, the human mind is next led to inquire what is the nature of this light which is so universally spread over the world, and what are its properties; nor have these subjects remained uninvestigated. The celebrated philosopher Descartes was of opinion that light is caused by a certain motion or undulation of a very thin elastic medium, which he supposed pervaded space; but Sir Isaac Newton, whose valuable discoveries established a new era in the history of science, discarded this doctrine, and from various observations, came to the conclusion that light consists of very minute particles of matter, which are thrown out in all directions from luminous bodies. The opinion of Descartes was afterterwards supported by many scientific men of eminence; but the views of Sir Isaac Newton appear better founded, and are consequently more generally countenanced. The particles of light are extremely small, nay, so exquisitely minute, that they do not affect the most delicate balance; but when we call to our recollection, that objects exist of such extreme minuteness as to escape even the powers of the microscope, so also does matter exist of so subtile a nature as not to affect the most exact scale that has as yet been constructed. This is the case with the matter of heat, and also with that of electricity. We may weigh, perhaps, the thousand part of a grain, but, says Dr. Thomson, we are certain that no particle of light weighs the *one millionth millionth* part of a grain. This exquisite minuteness of the particles of light enables

them to enter freely into the eye, without inflicting the slightest injury on the structure of so delicate an organ. Rare indeed is the adaptation of every arrangement of nature to fulfil its final end or purpose. The number of these particles which flow from every luminous body is also wonderful. It has been estimated that there flow more than six million million times as many particles of light from a candle in one second of time as there are grains of sand in the whole earth. Be this as it may, the particles of light from a single candle, if there be no obstacle in the way to obstruct their passage, will fill a space of two miles distance in every direction. The velocity with which light travels has equally excited the wonder and admiration of every intelligent mind. The sun is above ninety millions of miles distant from our earth, yet its light reaches us in about seven minutes and a half.—Dr. Brewster says, that it moves at the rate of a hundred and ninety-two thousand five hundred miles in a second. But while we pause on this surprising velocity, it may be well to recollect that all our notions of distance and time are merely comparative, and in this, as in many other instances, our ideas are confined to the limits of our own circumscribed experience. We know that the swiftest race-horse can scarcely ever run more than a mile a minute, nor can he support this speed more than one or two minutes; but the swallow does this with ease for nine or ten hours a-day. The golden eagle, it has been confidently affirmed, will wing its way, through the fiercest storm, at the rate of forty miles an hour; while the little swift, one of our smallest birds, flies at the rate of two hundred and fifty miles an hour. It is well known from actual experiment that sound travels eleven hundred and forty feet in a second, and in all these instances the rapidity of motion is almost incredible, but we must never allow our scepticism to be excited by what at first sight appears to be beyond the range of possibility. A stream of these particles of light, emanating from the sun, or any luminous body, constitutes what is called a ray of light which at all times proceeds, so long as it meets with no obstruction, in a straight line. Thus we can see through a straight, but not through a bent tube. In aiming with a gun at the bull's eye in the centre of a target, our endeavour is to direct

the bullet along the straight rays of light which proceed from that point to our organs of vision, and to enable us to take a surer aim, we generally close one eye in order to exclude all the rays of light excepting those which proceed from the point to which the attention is directed. We accordingly say that a ray of light moves in a straight line; but if it meet with a body, such as a mirror, that interrupts its progress, what is the result? It is unable to proceed directly onwards, and is reflected out of its course as a stone is when struck against a wall. This is called the reflection of light. On a clear summer's day, when the sun is shining on the bosom of a lake or river, its rays of light are thus turned or reflected back to the eye, with a brightness so overpowering as to be frequently insupportable. So likewise in walking on the sunny side of a street, the reflection of the rays from the pavement and houses dazzle the eyes, and induces us to seek shelter in the shade. On the sandy deserts of Africa and Egypt the continued reflection of the sun's rays from the sand gives rise to painful maladies of the organ of sight. It is for the same reason that when we walk out after a fall of snow, if the noonday sun shine brightly, the number of rays that are reflected from the snow around causes a painful sensation in the eyes. Travellers who have visited the northern latitudes have complained much of the annoyance they had to endure from this reflection of light from the snow and ice which perpetually exist in these dreary regions. The Esquimaux are not even reconciled by habit to this inconvenience, but are subjected to inflammation and other diseases of the eyes; many persons having, says Captain Lyon, lost their eyelashes and were nearly blind. But if such be the distressing consequence of the sun's rays, it may be asked, how comes it that we ourselves do not experience more annoyance from this cause? By the knowledge conferred on us by science, we are enabled to explain the reason, which is simply this—that while certain bodies do reflect all the sunlight, others take up or absorb it in a considerable quantity, so that only a part of it is reflected. Thus a soft dark earthy soil allows the rays of light to enter into it, and they there remain retained. It is this power which certain bodies have of absorbing light, that

prevents our having to walk through a world in which we should otherwise be continually dazzled.

We have thus far alluded very generally to the reflection and absorption of light; but there is another interesting property it possesses, which we will shortly consider, as it gives rise to some of the most beautiful and curious appearances in nature. When a ray of light proceeds through the same medium, we will say the air, it moves in a straight line, and if admitted into a dark room, through a hole in a shutter, appears white: but if it passes in a slanting direction from a rarer into a denser medium, as from air into water, it is then urged out of the straight line, and appears as if it had been suddenly bent. For this reason, a straight rod or stick, when immersed in water, appears to be broken at the surface of the water, and the portion immersed seems to be bent upwards. The light thus proceeding out of its straight course is said to be refracted, and our observations on objects placed in water are liable from this circumstance to considerable deception. For example,—a deep bodied fish seen near the surface of the water appears a flat fish; a round body there seems oval; and objects seen at the bottom of the water do not appear to be so deep as they really are; from which source of error, judging of the depth of a clear river from the bank, people have been frequently tempted beyond their depth, and, not unfrequently, drowned. Now, we must not forget that light, in passing into our atmosphere, has moved from a rarer into a denser medium—that is, from the thin ether above the highest stratum of the air, into the thicker mass of air which more immediately surrounds the earth. This air is generally loaded with watery vapour, so that the medium through which light has to pass in our atmosphere undergoes many remarkable changes. Hence the distance, height, and relative position of mountains, hills, vallies, and towns often appear altered. A certain range of mountains in one condition of the atmosphere will appear nearer; in another, more remote from the spectator than usual. But in being thus bent out of its course, a ray of light exhibits a variety of beautiful colours, the cause of which Sir Isaac Newton satisfactorily explains. We have already observed that if a ray of light be admitted through the hole of a shutter into a dark room, it appears

of uniform whiteness, but Sir Isaac discovered that this white ray of light is a combination of seven different coloured rays, which by a prism (a triangular piece of glass,) may be separated easily from each other. This indefatigable philosopher proceeded with his experiment thus.—he made a hole in one of his window-shutters, and having darkened his room, let in a convenient quantity of the sun's light. He next intercepted this light with his prism, and found that in passing through the glass, the light was so refracted as to exhibit on the wall an image of seven different colours, viz., violet, indigo, blue, green, yellow, orange, and red. "It was at first," says he, "a very pleasing divertisement to view the vivid and intense colours produced thereby:" and we may suspect what might be the feelings of the illustrious discoverer, from what we ourselves have felt on trying the experiment more than once. After varying his experiments in a most ingenious manner he established this interesting fact, that every ray of white light consists of seven other primary and different coloured rays, each of which seven is more or less refrangible than the other. Sir Isaac having obtained the seven different coloured rays, gathered them again together by the aid of a lens (a glass spherically convex,) and re-produced the white ray of light. Further, in corroboration of this, he mixed together one part of red lead, four parts of blue bise, and a proper proportion of orpiment and verdigris. This mixture was dun somewhat resembling wood newly cut. He took one third of the mixture and strewed it over the floor of his room, where the sun shone upon it through the open window, and beside it, in the shadow, he laid a piece of white paper of the same size. Then going to the distance of twelve or eighteen feet, so that he could not discern the unevenness of the surface of the powder, nor the little shadows let fall from the gritty particles thereof, the powder appeared intensely white, so as to transcend even the paper itself in whiteness. Sir Isaac Newton's discovery, that the combination of these different coloured rays produced the white ray of light, and that each of these elementary or primary rays possessed its own specific degree of refrangibility, revealed at once the explanation of many of the most interesting appearances in nature. Nothing can be more

beautiful than the colours with which the tops of mountains, the surface of the ocean, and the different shaped clouds are tinged at sunrise and sunset, the cause of which now became perfectly plain. The white rays of the sun, entering into an atmosphere of varying density, pass through it like the sunbeam through Sir Isaac Newton's glass prism, and are in a similar way decomposed. The rays that are the least refracted or bent from their course reach the earth in all the purity and beauty of their own individual colours, and enter into a thousand varied combinations. When the sun is shining in all its noon of brilliancy high above the horizon, its rays, falling on the wide expanse of the ocean, are reflected back unchanged in all their original silvery splendour; but when the sun is setting, and its rays fall slanting on the face of the waters, the red, being the least refrangible of the primary rays, floods with a fiery glow the moving billows, and the line of the visible horizon. Around the heavenly bodies—the sun and the moon—circles of light of the most varying colours frequently appear, which may be explained on the same principle, these halos being nothing more than the rays of light reflected and refracted by the small round particles of vapour through which they pass before reaching the sphere of our vision. But the most familiar instance of the decomposition of light into its prismatic colours is exhibited to us by the rainbow, which is occasioned by the light of the sun shining on the globular drops of water falling in an opposite shower. In this instance the rays of white light are refracted or resolved into their primary rays, which are reflected in the form of an arch across the firmament. Sometimes more than one or two of these arches are formed. Captain Parry informs us that he saw five rainbows at one time, and each complete. Sometimes the arches intersect each other, and they have been seen in an inverted position. Lunar rainbows also frequently occur, but do not display such variety of colours. Rainbows also frequently appear among the waves of the sea, when their tops are buffeted by the winds, and blown into small globules. They appear, too, occasionally on the ground when the sun shines on a very thick dew. The falls of Niagara, and those of less note—even small cascades and fountains, whose

waters in falling are divided into drops, display rainbows when the spectator is in a proper position to observe them. But the most remarkable consequence of the refraction and reflection of light is the numerous atmospherical deceptions which are thereby occasioned. Places at considerable distances are sometimes unexpectedly brought within the sphere of vision. In the Records of the Transactions of the Royal Society of London, we find that in 1788, the coast of France was distinctly seen at Hastings. Towns, hills, valleys, islands, ships, &c., have been seen reflected in the heavens. In the county of Huntingdon, on the morning of July 16, 1820, at half past four o'clock, the sun was shining in a cloudless sky, and the light vapours that arose from the river Ouse were moving over a little hill near St. Neots, when suddenly the village of Great Paxton, its farm-houses, barns, dispersed cottages, trees, and its different grass fields, were clearly and distinctly visible in a beautiful aerial picture which extended from east to west about four hundred yards. Nothing could exceed the surprise and admiration of the spectators as they looked at this surprising phenomenon, nor their regret at its disappearance in little more than ten minutes. Among the Hartz mountains in Germany, at Soutra Fell in Cumberland, in the south of Italy, and in several other places similar phenomena have been observed. In the Memoirs of the Wernerian Society of Edinburgh for 1827, appears an account of the Skerry Islands, situated in the sea about four miles distant from the north coast of Ireland, appearing at an extraordinary elevation, apparently 200 yards above the level of the sea, breaking off by degrees in the centre into appearances resembling old castles, towers, and spires. Two or three of such images in an inverted position are sometimes seen one above the other. In the neighbourhood of Edinburgh, Inchkeith, an island in the Frith of Forth, has been seen reflected in the sky in an inverted position above the island, and above that another picture of it in its natural position. In the northern seas, owing to the peculiar refractive state of the atmosphere, such appearances are of frequent occurrence. When the rays of light fall on the surface of the ice, they are thence reflected into the air above, and often produce an aerial map of the ice and sea below. This is called the iceblink.

Nothing can exceed the curious, and at the same time splendid exhibitions, presented by the unequal refraction of the light from the ice and the land in these desolate regions. Captain Scoresby says, hummocks of ice assumed the forms of castles, obelisks, and spires; in some places the distant ice was so irregular, and appeared so full of pinnacles, that it resembled a forest of naked trees; in others it presented the character of an extensive city, crowded with churches, castles, and public edifices. He also records several instances of ships being seen reflected one above another in the sky, at a time when the ships themselves and the images were so distant as to be recognized only by the aid of a telescope. We have already explained how the rays of light become refracted in passing from a rarer into a denser atmosphere, and the frequency of these appearances in these regions is owing to the varying and unequal density of the atmosphere, which, when moist and warm, becomes chilled and condensed by passing over the extensive surfaces of ice.

Light produces the most important and beneficial effects on the inanimate and animate Creation, and, without its gracious agency all nature would sicken and die. Many substances such as oils, mineral acids, preparations of mercury, silver, lead, &c., change their colour when opposed to light. Those parts of a room which are painted with white lead and oil, and defended from light by furniture, become darker than the rest, but on exposure acquire the same brightness. Plants, raised in the open air, when placed in darkness, become pale, and fade in two or three days; those which after having been raised in darkness, have been exposed for a time to sunlight, cannot support the want of light, but decay. Plants that grow beneath stones are white, soft, watery, and insipid, of which fact many gardeners avail themselves to furnish our tables with white and tender vegetables, by binding up and compressing their leaves together, so as to defend them from the contact of light. The light of a lamp can, although but imperfectly, replace that of the sun. The plant becomes green and inclines to the light; but this artificial light has a more beneficial influence when reflected from mirrors; and hence many hill-sides are rendered peculiarly fertile by the similar reverberation of the light. When the sky has been long obscured by clouds, the

leaves of trees and grass lose their usual bright green colour. This is corroborated by an American Professor, who says, "Clouds and rain have obscured the hemisphere during the last six days. In that time, the leaves of all the forests which are seen from this place have greatly expanded, but they were all of a pallid hue until this afternoon, when, within the period of six hours, during which we had sunshine, they all changed their colour to a beautiful green."

The entire absence of light is so injurious to plants, that it has been concluded, that without the light of the moon and stars, night would destroy vegetables. The complexion of man, and the colours of the different races of animals, are considerably modified by exposure to light. African ladies, who live much within doors, are not so dark as those persoes who spend much of their time in the open air. Animals in the polar regions do not exhibit the variety of colours which those present that are natives of tropical climates. In this country likewise, we observe that foxes, rabbits, hares, &c., assimilate to the colour of the soil they frequent. Birds, too, that fly by night do not display so varied and gaudy a plumage as those which fly by day. Animals, if totally deprived of light, would, like plants, languish and die. Nothing, indeed, can be more appalling than total darkness; and for this reason the denunciation of Him who made the sun and the moon is so terrible, which declares that the wicked shall be cast into outer darkness, where there shall be weeping and wailing and gnashing of teeth.

Having thus explained, in a general manner, the sources, the nature, and the effects of light, we shall now proceed on the same principle—that is, endeavouring to explain every thing in the most simple manner, and avoiding as much as possible the introduction of scientific terms—to devote our attention to the subject of

HEAT.

In taking a view of the magnificent theatre of nature, we at once perceive the vast importance of this agent :—by its power, rocks, islands, hills, and mountains have been upraised out of the innermost depths of the earth :—by its operation, the genial moisture, which, under the form of rain, descends, cooling the heated air, and refreshing the parched up soil, is raised from the bosom of rivers, lakes, and seas ;—by its influence, the waters which were chained up by frost during the desolate reign of winter, are again set free to sparkle along at the bases of their sunny banks :—by its benignant agency, the trees, that were deprived of their foliage, and the herbs, that were apparently withered, are again invigorated with new life, and arrayed in new beauty ;—it controls and modifies, indeed, life under every form ; and is the most universally pervading and important agent with which we are acquainted.

When we consider the dreary monotony of the polar regions, where human nature appears in its most humble and degraded form, and where the bears, wolves, and foxes seem alone to find appropriate habitations ; and when we compare these trackless solitary wastes with the blooming valleys of sunny Italy, we at once see the vast influence of different temperatures on the surface of the globe ; nor do we hesitate to refer such modifications to the sun, which is undoubtedly, the principal fountain both of heat and light. At a period when science was in its infancy, the ancients observed this general fact, and concluded that the sun was an immense globe of fire ; but this opinion has long since been exploded. The astronomers of our own more enlightened age, have shown, by the aid of telescopes of vast power, that the sun is itself a solid and opaque body, perhaps a habitable globe, and they have come to the conclusion that we owe both its light and heat to the peculiar atmosphere by which it is surrounded. Although this opinion has been advocated

by Sir William Herschell, it must be acknowledged, that the manner and region of the sun in which heat and light are generated, can by no means be understood, and on this, as on every other subject of inquiry, it is better to confess our ignorance, than to raise up a plausible and satisfactory knowledge. Certain it is, that the rays of the sun do impart heat; but it must be observed, that they do not so unless they come in contact with some solid body—that is to say, they pass freely through the air without giving out any sensible heat until they reach the surface of the earth. Accordingly the higher we ascend in the air the colder it becomes—a fact experienced by those who have ascended in balloons; several of whom have, on such occasions, found the thermometer sink a great many degrees, even below the freezing point. It is from the same cause that the higher we ascend a mountain, the more intense does the cold become, so that we at length arrive at a region where we can trace no signs of animal or vegetable life, all around being shrouded in perpetual snow. When the traveller ascends the Cimborazo mountain, which forms the extremity of the Andes in South America, and which rises to the height of twenty thousand nine hundred feet above the surface of the earth, he leaves at its base a hot region, where the exhalations of a marshy soil, and the continuance of heat, generate fevers and diseases fatal to animal and vegetable life. Ascending higher, he arrives at a temperate region, which possesses a moderate and constant warmth and is a perpetual season of spring to those who have arrived from the lower, summer-like, hot region. Above this again, as he ascends still higher, he finds himself surrounded by ice and snow, and then suffers the most intense winter cold, so that it may be truly said, that summer, winter, and spring, are here seated on three distinct thrones, which they never quit, and where they are constantly surrounded by the attributes of their respective powers. Vegetable and animal life present us with equally remarkable gradations, in these different regions—thus, the forests of the lower or burning regions are remarkably rich, and they continually resound with the howlings of different tribes of monkeys, and the ant-eater and black tiger prowl about them, while the surrounding air is infested with

myriads of mosquitoes and other obnoxious insects. Higher up the mountain is found the most splendid palm trees, upon which the sloth may be seen hanging, and at the feet of which the terrible boa-constrictor and crocodile may be often seen extending their frightful forms. Above this region is met the most beautiful aborescent ferns, and the precious bark tree, and many flowers of surpassing beauty; but here, the air becoming colder, the sensitive plant, as if giving warning of the sterility and lifelessness of the region to which we are approximating, loses its peculiar sensibility, and no longer closes its leaves on being touched. At length, as we ascend higher, the gigantic trees appear to have dwindled: the eye rests on nothing but short stunted dwarfish shurbs and alpine plants, until at last the lichins and mosses amidst patches of scattered snow apprise us that we have arrived at the boundary of organized beings and that above us is nothing save the dreary region of eternal winter. Here no animal is observed, excepting occasionally the great condor, which is the only living being that appears to inhabit these dismal solitudes. It is obvious that here there is a regular gradation of temperature from the surface of the earth to the upper regions of the air; and for one hundred and ten yards of ascent, the heat diminishes as much as if we were to advance one degree of latitude towards the northern polar regions. The facts here described are of the utmost importance, because from these we observe that certain parts of the world are rendered not only habitable, but possess a fine and genial climate, which would otherwise be parched up by a tropical and burning sun. For example the city of Quito is almost under the equator, and were we to form a superficial judgment of its temperature from its situation, we might conclude that it would be oppressed with intolerable heat, instead of which, owing to its elevation, the air of that city differs little in temperature from that which we find in Paris.

It is, therefore, obvious that the rays of the sun do not produce heat unless they strike upon some solid body, and even the greater or lesser intensity of the heat they produce is greatly modified by the direction which they take, for when these solar rays fall directly or vertically on a particular district, they give out much greater heat

than when they fall obliquely. The reason for which is simple; when they descend upon a spot directly, they fall on it with much force, and a great number of them are included in a small space; whereas, when their direction is more slanting, they not only do not strike the spot with the same force, but are more scattered, so that they by no means produce the same intensity of heat. By this general fact, then, we are enabled to explain the diminution of temperature from the equator to the poles—that is from the tropical to the frigid regions. Near the equator we find a zone, which passes immediately under the sun twice a year, and receives its rays in a very direct or vertical manner; and here we have the tropical region. Next, we find a portion of the globe, which does not receive the sun's rays so directly, but, on the contrary, more obliquely, so that less heat is produced, and here, therefore, we find the temperate region. After this we reach another region of the globe, which is altogether deprived of the heat of the sun for the greater part of the year, and, during the other receives its rays still more obliquely: and here, consequently, we have the frigid zone, that desolate region of eternal ice and snow, which has been explored in vain by so many intrepid navigators. This variety of temperature, occasioned by the different direction which the sun's rays take in reaching the earth, is remarkably obvious in hilly countries. If a hill, having a southerly aspect, present a certain inclination, and the sun be at a corresponding altitude, the solar rays will strike the side of the hill perpendicularly, while on the plain below and around, the rays strike the earth obliquely, and with a proportionate diminution of force. If the ground extend to the north, it will receive no rays, and remain always in shade; and it is on this account that in the Valais we see the Alps on one side covered with eternal ice, whilst the opposite hills are adorned with rich vineyards, and orchards, and all the charms of fertility. Nor is the different manner in which the rays of the sun strike the earth the only circumstance to be considered in examining the temperature of different climates; for the rays of heat, like the rays of light, undergo a greater or lesser reflection; that is when they strike the earth they are thrown back into the atmosphere, and are more or less confined and diffused among the

watery vapour with which it is always loaded. Hence arises the warm and genial temperature which surrounds the immediate surface of the earth, and which is so admirably adapted to support animal and vegetable life. Some soils likewise absorb the sun's rays more than others; thus, a moist clayey soil takes up and retains the rays of heat for a considerable time; a dry sandy surface, on the contrary, immediately reflects them; and thence it is that the traveller, in journeying through the sandy deserts of Africa, experiences the most oppressive and almost intolerable heat. This is aggravated by the dryness of the air, for when it contains much moisture, as is the case over marshy soils, the heat is considerably diminished; but such marshes in hot countries undergo fermentation, and give rise to exhalations that produce the most pestilent diseases. The vicinity of the sea also very considerably moderates the effects of temperature; and on this account the interior of continents is colder than their coasts. So intense is the cold in the mountains of Norway, that it proved fatal to most of the Swedish army during the war, the dead bodies of the soldiers having been found in great numbers; but those who live on the coasts of that country enjoy a very mild and agreeable climate. When the sun's rays fall on the surface of the water, part of them enter it, and the continual motion of the waves, presenting a cool and fresh surface to the heated air, it is cooled, so that, while the land air is heated, and rises up into the upper regions, a cool sea breeze springs up and rushes in to supply it place. The vicinity of the sea, therefore, moderates the heat of summer. It is also well known that the temperature of water is always more equalised than that of land, and, consequently, in winter, when the sun's rays fall very obliquely on the earth, and its surface is covered with snow which prevents the heat of the earth radiating into the air, the sea, having a more uniform temperature, continues to radiate heat, and thus a warmer region of air is formed, which modifies the cold of winter. On this account, at Plymouth, although the mean heat of the year is, on the whole, a little less than at Paris, the winter months are much less severe. Also, in the coldest winter months, the temperature of Edinburgh is some degrees warmer than that of London. From what we

have stated, it must appear obvious that, while we regard the sun as the principal source of heat, yet the heat is modified by the direction which the solar rays take in reaching the earth, by the reflection and absorption which they there undergo, and by the vicinity of the sea.

We have as yet only considered the heat produced on the surface of the earth by the direct and immediate action of the sun; but, independent of this, we have conclusive evidence of the existence of very intense heat in the central depths of the earth. In descending into deep mines, the temperature of the air has been found to increase as we go down, but the presence of the miners, the lamps they use, and the explosions of gunpowder, render many of such experiments very erroneous. Other methods, therefore, have been adopted to examine into the truth of the supposed fact, such as boring and cutting niches into rocks, taking at the same time every possible precaution against all sources of fallacy. The result has still been the same, and leads to the conclusion that a very great heat exists at a depth of the earth beyond the sun's influence. The hot springs, which abound not only in volcanic districts, but in various other parts of the world, also lead us to the same inference. The most remarkable springs of this kind are found in Iceland, where the principal one is called the Geyser, situated in the middle of a plain and surrounded by forty other springs of a smaller size. These throw up their waters to a very considerable height. The eruption commences with short jets, which gradually increase in size; the steam then rushes forth furiously, accompanied by a loud thundering noise, resembling the distant firing of artillery from a ship at sea, until at last a great mass of water is raised to a height of seventy, eighty, or ninety feet. The Icelanders use the more temperate of these springs as warm baths; in those that are hotter or boiling they boil their various articles of food, taking only the precaution to cover the vessel used to prevent the volcanic odour giving a taste to their food. Volcanoes are also unquestionable proofs of the existence of this subterranean heat, which must exist at a considerable depth in the earth, because rocks, which are well known to have their original position at such depths, are, during their violent action, ejected into the air actually liquified by heat.

Some of these volcanoes seem to have exhausted themselves and have become extinct, examples of which are to be found in the central parts of France and Germany. Others exist in a state of frequent or continual activity, such as Vesuvius, Ætna, Stromboli, and Hecla. Besides which, we are aware, that owing to violent volcanic action, immense rocks are forced up from a considerable depth, even from below the surface of the sea, and so form islands. In July of the year 1831, an island of this kind arose in the Mediterranean. The water was at first violently agitated, after which vast quantities of smoke and steam were evolved, and enormous masses of hot cinders, dust, &c. ejected several hundred feet into the air. Captain Steunhouse landed on this island the following month, and estimated its circumference to be about a mile and a quarter. It is supposed that rocks so formed are of igneous origin, and of such rocks there are numerous examples in the immediate neighbourhood of the city of Edinburgh. In examining either of which it is at once perceptible how these igneous rocks have rent asunder and forced their way through superincumbent strata, now filling up the immense crivices they have torn open, and now overrunning the whole subjacent mass. When these vast and powerful operations of nature took place, terrible and sublime, indeed, must have been the convulsions exhibited, and altogether beyond the range of the human imagination.

From what has been stated—from the temperature increasing in the deeper parts of rocks and mines—from the existence of hot springs in various parts of the world—from the phenomena exhibited by volcanoes, and the appearances of rocks that have visibly undergone a state of fusion, we are entitled to believe in the existence of heat as a most important agent beneath the surface of the earth; and whether it arise from central fire, or whether it be generated by some remarkable chemical actions that are in progress, has not as yet been satisfactorily determined.

But in taking this general survey of the sources and influence of heat in nature, we ought not to forget, that it is frequently seen to arise from electricity. Even in Great Britain where thunder storms are neither so frequent nor so violent as in many other parts of the world

nothing is more common than for lightning to melt metallic substances, especially iron. In a great thunder storm that happened in Herefordshire, a few years back, the thick band of iron that was used to support a wooden railing in a field adjoining to the city of Hereford, was completely melted between each piece of wood—a fact which at once shows how intense the heat must have been. In Italy, where such occurrences are not so rare, previous to the removal of the remains of the celebrated poet Ariosto from the Benedictine church to the Library of Ferara, his bust, which surmounted the tomb, was struck by lightning and the crown of iron laurels melted away. Lord Byron has recorded the circumstance, in the following stanza in the fourth canto of Childe Harold:—

> "The lightning rent from Ariosto's bust
> The iron crown of laurels' mimic leaves,
> Nor was the ominous element unjust—
> For the true laurel leaf which glory weaves,
> Is of the tree no bolt of thunder cleaves,
> And the false semblance but disgraced his brow;
> Yet still it fondly superstition grieves,
> Know what the lightning sanctifies below
> Whate'er it strikes. Yon head is doubly sacred now."

When we take into our consideration the operations of heat on the capacious and splendid scale of which they really take place in nature, it may readily be supposed that man would be led, even before the sun of science shone upon the world, to contrive some plan of procuring that peculiar modification of light and heat which constitutes fire; nor is it to be wondered at, that so many remarkable superstitions were attributed to it by the ancients. It is generally well known that the Persians worshipped fire. The patriarchs used it in their burnt offerings; it was kept constantly burning in the Jewish tabernacle, and was regarded as the origin of life, the soul of the world, and the visible symbol of the Deity. We have already explained how it has been procured artificially by friction, as well as by concussion, and likewise stated that it might be kept up by the burning of inflammable bodies, which is called combustion. The compression of the particles of bodies nearer to each

other is always more or less attended by an evolution of heat; and this is the case with air; for if a quantity of air be confined in a syringe, in which there is a piece of tinder at the bottom, and then violently compressed, sufficient is produced to ignite the tinder. It has also been shown by a member of the Academy of Paris, that water itself, when submitted to a pressure of twenty atmospheres, gives out a certain quantity of heat. But it may be asked what is the nature of heat? of what does it actually consist? We shall simply reply that there are two opinions advocated; the first, that heat consists of nothing more than a certain vibration of the particles of the hot body; the other that it does not consist of any such vibration, but is itself, an independent substance, being an extremely subtile and elastic fluid, contained and dispersed among the pores of matter. This latter opinion appears to be the most plausible, and among reasons for thinking so, we may state the following two: The first is, that the addition of heat to a body increases its bulk, leading us to suppose that it receives some addition; the second is, that bodies throw out their heat to a considerable distance, which could scarcely happen unless the heat so solved was distinct, and independent of the body itself whence its proceeds. Heat, therefore, we conclude, is a very subtile and elastic fluid; but we may here mention, that some philosophers consider light and heat are only modifications of each other, and this opinion has been very ingeniously supported by Sir John Leslie, of the Edinburgh University. Whatever be the abstract nature of heat, its accumulation in, or abstraction from different bodies, gives rise to the most remarkable changes; a few instances of which we will introduce as we proceed in our description of *The Properties of Heat, and its Effects.*

Without heat the earth would not pour forth its numerous streams, nor be clothed with verdure—nor would the air be refreshed with genial moisture—neither would the humblest of living beings be enabled to support its own bare existence.

We have said that heat is a fluid, because like all fluids, it has a tendency to seek its own equilibrium, that is to say, to distribute itself equally in every direction. Suspend a ball of iron, red hot in an apartment, and the heat

from it disperses itself equally through the cooler air, until one temperature pervades the ball and surrounding air. A fire placed in a grate diffuses its heat equally until every object in the room arrives at the same temperature. And well it is so; as were it not for the tendency of heat to equalize its distribution, it would accumulate in large and irregular quantities, and we should be exposed to the most painful transitions, and hurried continually from the sufferings of the most excessive heat to the equally intense agonies of the extremest cold, like the unhappy spirits described by Dante and Milton—

> "Thither by harpy-footed furies hurl'd
> From beds of raging fire, to starve in ice."

Heat therefore seeks its own equipoise; it also enters in greater or lesser quantities into the pores of all bodies; but some do not allow it to pass through them so readily as others. If we place one end of an iron rod in the fire, the heat passes so quickly through the whole length of the rod that in a short time we cannot touch the other end without being burnt; but we may hold one end of a short stick in our hand while the other is actually blazing, so slowly does the heat pass through the substance of the wood. Metallic vessels, used for containing hot fluids, require wire, bone or wooden handles, which being very slow conductors of heat, interrupt its communication to the hand. Those bodies which allow heat to traverse through them very quickly, are called good conductors—those that retard its progress, bad conductors of heat; and it has been found that the densest bodies are the best conductors. Silver, gold, copper, iron, allow heat to traverse them more readily than glass, wood, porous earths, and bodies of a looser texture. Fluids, owing to the mobility of their particles, receive and transmit heat better than solids; hence when a hot body is plunged into water, it cools more quickly than if it were plunged into a mass of sand. Air is not a good conductor of heat, which is another admirable provision; for if it allowed its transmission as readily as the metals, the heat from the surface of the earth would be so rapidly carried away, that nothing would be able to support life. But it has been discovered that air in a state of absolute rest, does not conduct heat at all—and this is a fact of the

greatest importance. On a hot summer's day, when there is scarcely a breath of wind stirring, the oppression we feel is in a great measure owing to this cause, for we are then moving in an atmosphere which does not carry away the accumulating heat of the body. Furs, wools, feathers, and loose spongy substances, are bad conductors of heat, for the air which is retained between their interstices, and which are at rest, prevents its transmission through them. Such materials are therefore chosen for winter clothing, not, as is the general idea, because they contain or impart any heat, but simply because they prevent its escape from the body and protect us at the same time from the external cold air. Thus protected, many of our boldest and most intrepid navigators have braved the winter of the polar regions, and lived with impunity amidst the coldness of these desolate solitudes, which seem to place an eternal barrier against the further extension of human knowledge or of human dominion.

Prodigal in her beneficence, nature has provided an appropriate and adequate covering for the animals of the different regions on the face of the globe. Those living in hot countries have the hair of their coat fine, thin, and short; in those again that frequent more temperate climates, their hair becomes thicker and woolly; while those in the coldest countries, in high latitudes, their coat becomes shaggy, coarse and thick. Animals that live much in water, are provided with the finest, longest, and thickest furs; and in all instances the fur is thicker on the parts of the body most exposed, more especially on the back, because the heat escaping upwards, requires a greater obstruction in that direction. Birds frequenting the higher regions of the atmosphere require not only that their bodies should be light, but well protected from the cold, which, as we have already explained, increases as we ascend into the higher regions of the air. We find that nature has not been unmindful of these requirements; for in these birds the body is not only rendered light, by their bones being hollow and communicating with the lungs, so that they are always filled with air, but they are enveloped in a manner which does not allow their natural heat to be easily carried off; their plumage, also, so beautiful to the eye of the spectator, is likewise an admirable protection against cold, for the quill, shaft, and

web of the feather are so constructed as to offer the necessary obstruction to the escape of heat. The feathers, too, vary in kind and quantity, according to the habits of the bird, the climate it inhabits, and the season of the year. But there are animals destined to live in the northern seas, which are exposed to a much more intense degree of cold, yet which are not protected either by feathers or furs. They are, however, provided with an equally efficient defence, for under the skin, disposed in small cells, large quantities of fat, or thick oil are imbedded, which completely envelopes the whole body. Such is found in the whale, the seal, and the walrus; and the oil that is thence procured is well known to be a very important article of commerce. In all these instances, and numerous others needless here to mention, such coverings operate simply as non-conducters of heat; preventing at the same time the escape of the natural warmth of the body, and the penetration into it of the external cold. Man, taught by observation and experience, has taken advantage, as already remarked, of these facts, to supply himself with winter clothing; and according to experiments made by scientific men, it appears hare fur, and eider down are the warmest materials for such apparel; after beavers' fur, raw silk, sheeps' wool, and cotton wool, and after them lint, or the scrapings of fine linen.

From what we have stated, we presume that it is understood that heat has at all times a tendency to distribute itself equally in all directions, and that some bodies allow it to pass through them more readily than others; which facts will now enable us to understand the cause of our sensations of heat and cold. When several bodies of equal temperature are placed together, they each give out and receive the same quantities of heat, so that there is no increase of the temperature; but when bodies of different temperature are placed in contact with each other, the hotter gives out heat to the colder body, until the same temperature is established between them;—for example, when the hand takes hold of a body colder than itself, it becomes sensible of cold, because a portion of its heat is conducted away by the colder body; but if it grasp a body that is hotter than itself, then the body of higher temperature communicates to the hand, which becomes sensible of warmth. In all these instances the intensity

of the sensation depends on the superior or inferior conducting power of the body grasped, for the more rapidly the heat is carried away from the hand, the more intense is the sensation of cold thereby produced. The carpet in a room of usual temperature, feels nearly as warm as the hand; the table feels rather colder; the marble chimney-piece colder still; and the fire-irons coldest of all; but each of these will, on the application of a thermometer, be found of the same temperature, and the difference of the sensation is produced only by the greater or lesser rapidity with which they severally conduct away the heat from the body. Our sensations of heat and cold, therefore, are merely relative; for even ice, when carried into a room, the temperature of which is below the freezing point, will radiate heat. Snow appears cold to a healthy hand; but it is frequently applied to frost-bitten limbs, because it is warmer than limbs so affected; the object being to apply heat in the most gradual manner. Two persons bathing, will, according to the heat of each, find an apparent difference in the temperature of the same stream. A person from India arriving in England, in the spring season will complain of coldness, although the inhabitants in that country are beginning to cast aside their winter apparel. The great danger which arises from going out a heated ball-room or a theatre, is occasioned by the transition of the warm body into a colder atmosphere; by which many lives are annually sacrificed, as it were, on the shrine of pleasure; and the seeds are sown, by which the fairest, and the loveliest of the land, fall victims of lingering consumption.

Heat is an agent of so subtile and diffused a nature, that we have not discovered any kind of matter that is totally destitute of it, and its accumulation, or abstraction, in various bodies, must neecssarily effect great changes in them. It is a well known fact, that the solid particles of all solid bodies are held together by a power of attraction which they exert among themselves, and which is called the attraction of cohesion, or aggregation; but no two particles of matter are ever in actual contact. Interstices of greater or lesser magnitude must exist between them; and it is into these that heat insinuates itself. It is evident therefore that heat must produce expansion; for, by accumulating, it must stretch

these spaces, and force particles bounding them to a greater distance from each other, whereby the whole body must necessarily be increased in bulk. But as this accumulation of heat causes an increase in the size, so must its abstraction, by diminishing the size of these openings and allowing the surrounding particles to each other, occasion the contraction of a body. A few examples will suffice. An iron bar when heated cannot be made to enter an opening which, when cold, it will readily enter; of this fact coachmakers and others avail themselves. In making carriage wheels, they place the iron rim round the wheel while red-hot, then as the iron cools it contracts and embraces more firmly the wooden portion of the wheel. Even in this country, the heat of summer is sufficient to occasion the most remarkable changes in the condition of metallic bodies; for instance, the centre arch of an iron bridge is higher in hot than in cold weather; the gate of an iron railing, which during cold weather will open and shut easily, will sometimes stick fast on a warm day, owing to there being a greater expansion of it and the adjoining railing than of the ground in which they are fixed. The pitch of a piano-forte or harp is lowered during a warm day; and although tuned in a morning, will become out of tune if the same room be heated by a crowded party, owing to the expansion of the strings being greater than that of the frame-work of the instrument. Buildings of considerable size and strength have been very often much injured by the expansion of the iron bars fixed in different parts of them; a case of which kind happened only a few years since to Bow Church in London. In this church, the bars of iron, used to hold together its fine steeple, expanded during summer, and forced the stones sufficiently apart to allow dust and sandy particles to lodge between them; nor is there any doubt but that had it not been repaired soon enough, the whole edifice might have fallen. A very curious experiment upon the known expansion of metals by heat, occurred some time ago in Paris at the Abbey St. Martin, afterwards called the Conservatoire des Arts et Metiers. The immense weight of the roof of this building was forcing the walls asunder, when they were restored in the following ingenious manner, to their perpendicular position:—Holes were made at opposite

points in several places in the walls, through which, strong iron bars were introduced, so as to extend across the building, and their extremities beyond the walls. Large nuts were then placed upon their ends and screwed up so as to press upon the walls. Every alternate bar was then heated by powerful lamps, so that its length increased by expansion, and the nuts, before in contact with the walls, retired some distance from them. The nuts were again screwed up to the walls; and the iron bars, on cooling, contracted, and from the pressure of the nuts, the walls were drawn together so as to be restored to their proper position.

It must now be obvious to every reader, that the first effect of heat is the expansion of the body into which it enters; and when a still farther quantity is added, another change is produced, and the body however dense it may be, is converted into a liquid. Silver, gold, lead, iron, tin, and all substances with which we are acquainted, may thus be liquified, excepting the diamond, which being a combustible body, catches fire at a low temperature. The most remarkable circumstance attending liquifaction is this—when a body changes from a solid to a liquid, or from a liquid to a vapour, its expansion causes a sudden increase of its capacity for heat, in consequence of which it absorbs an additional quantity, which becomes fixed, and so concealed as not to affect the thermometer. This is what is termed *latent* (secret) *heat*. It is this addition of heat which occasions the body to pass from the solid to the fluid state; as thus, when ice is converted into water, it absorbs as much heat as it would, if it did not melt it, raise its temperature 140 degrees. On the other hand, before water can be converted into a solid state, it must, after being reduced to 32 degrees, part with this 140 degrees of heat, which occasioned it to exist in a fluid form. This is the reason that the processes of freezing and thawing are slow operations; were it otherwise, the cold of a single night might freeze an ocean, and the heat of a single day convert the accumulated snows of winter into a sudden and frightful inundation. When water has been heated in an open vessel to the boiling point, instead of its temperature increasing, the additional heat escapes in the form of steam, and this steam absorbs 1000 degrees of heat

which immediately becomes insensible. This is the reason, that when water is thrown upon a raging fire, it so powerfully represses it, that the heat enters so rapidly into its latent state in the conversion of the water into steam, that it is soon abstracted from the burning body.

It is now understood, that after expansion, the next effect of heat is to produce liquifaction; but if the heat be still continued, the material particles being forced to a still greater distance from each other, the liquid enters into a state of vapour. Water affords a favourable example of this, being easily vaporised; indeed it undergoes spontaneous evaporation at very low temperatures: but, on the application of cold the watery vapour is immediately condensed. When steam is first formed it is invisible, as may be observed by noticing it issuing from the spout of a tea-kettle; but when it comes into contact with colder air it is condensed, and assumes the appearance of a visible cloud. An immense quanitity of water is incessantly evaporating from the surface of the earth. The fields and roads are inundated after a heavy fall of rain, but the water soon disappears during a little subsequent fine weather. Many large rivers issue into the Mediterranean sea; still it never increases in size, owing to the continual evaporation from its surface. The water thus evaporated from rivers, lakes, and seas, ascends into the air, and becomes condensed into clouds. In this country it is seldom that the sky is perfectly transparent, but often on a clear day, we may observe a cloud suddenly formed by a cold current of wind in the upper regions of the air, which rapidly condenses the watery vapour there into light fleecy clouds. We may also add here, that water does not evaporate so quickly when still, as when agitated by a brisk wind; for this reason variable winds are generally regarded as the precursors of rain, and more rain falls during spring and autumn, than during summer and winter.

When a body has absorbed a certain quantity of heat, it distributes it forth again; and in so doing, the heat passes off from its surface in straight lines. When a solid substance is interposed, however, the rays of heat are intercepted, as is the case when we use a hand-screen to protect the face from the heat of a common fire. Several curious experiments have been made on this subject; and

it has been found that a rough and dark surface projects heat better than a smooth and polished one, so that metals do not radiate heat so well as other substances. Were it not for this radiation, the earth which has been absorbing the sun's rays for many days, would become parched up by the accumulation of heat; instead of which, when the sun has set, it again radiates it forth into the surrounding air. The consequence of this is, that the surface whence this radiation takes place becomes colder than the atmosphere which encompasseth it, and condenses the visible vapour which the air always contains into dew. Dew, we may remark, is only deposited on those substances that are below the temperature of the air by which they are surrounded; and as fibrous substances radicate heat best, the dew appears in greater abundance where it is most wanted, on the grass of open plains, rather than on bare earth, rocks, and masses of water. It is well known that dew is deposited most liberally on a fine clear night, and but little is produced when the sky is overcast with clouds—the reason of which is, that the clouds, acting like a concave mirror, reflect back the radiated heat to the earth's surface, and so tend to keep it warm. Snows act in the same manner; and by obstructing the radiation of its heat, keeps the earth below warm, while the air above is many degrees below the freezing point. Our own bodies radiate heat. When we go out into the open air at night, this radiation of heat induces a sensation of cold; and the coldness we experience is most intense when we are in an open country in a clear calm night. When it is cloudy the heat is reflected back to us; and even in towns the reflection from the houses affords to us some compensation; but in the country when the night is clear and calm, this radiation proceeds without interruption.

SPONTANEOUS COMBUSTION OF THE HUMAN BODY.

In explaining the different sources of light and heat, we have already observed that during the decomposition of animal and vegetable matter a certain gas is often generated, which ignites on coming in contact with common atmospheric air. The *ignis fatuus*, known also by the names of the *Will o' the Wisp*, and *Jack o' Lantern*, is occasioned by this gas; and the fact of its appearing in marshy districts, has given rise to the popular superstition amongst the vulgar, that it is an evil spirit endeavouring to mislead the luckless traveller to his destruction. The northern lights, so frequently witnessed in this country, have been attributed by some to the same cause; but we may hereafter explain that this theory does not satisfactorily account for this phenomenon. But that a certain combination of hydrogen gas, with a proportion of phosphoros, forms a compound which takes fire immediately on coming in contact with air can be proved by direct experiment, and, notwithstanding its incredibility, it would appear the human body itself may become so impregnated with these elements or other inflammable matter, as to take fire spontaneously and be almost entirely consumed. Human knowledge is so limited in extent, that we should pause before we venture to deny the possibility of any thing; for facts, which at first sight may appear difficult to believe, may be afterwards explained on very easy principles. Ignorant and vulgar persons may easily play the sceptic, and deny the possibility of every thing which passes beyond their own narrow and limited comprehension; but it remains for those who are possessed of higher abilities, to receive with a proper spirit, facts, sufficiently attested by disinterested witnesses, and to explain them afterwards according to the theories which may be suggested by the advancement of science. We shall in this place insert a few instances of spontaneous combustion; which have been recorded by witnesses

whose veracity cannot fairly be impeached, and which remain registered on the best authorities.

Cornelia Banoli, Countess of Cesina, an Italian lady, sixty-two years of age, having felt drowsy one evening, retired earlier to bed than was usual, and was attended by her maid until she fell asleep. When the servant entered her mistress's apartment on the following morning, for the purpose of awakening her, a dreadful spectacle presented itself to her view. At the distance of about four feet from the bed there was a heap of ashes, in which the head, legs, and arms of the countess alone could be traced. The head lay between the legs, but the half of its posterior part, together with the brain and chin, were entirely consumed. The legs and arms were uninjured. This case was communicated to the public by Dr. Cromwell Mortimer in the Philosophical Transactions in 1745.

The following is another case, the authenticity of which cannot be doubted. Don G. Maria Bertholi, a friar, who lived in Mount Volere, went to the fair of Filetto, and having walked about all day, retired in the evening to the house of a relation at Fenille, to spent the night. Upon his arrival he went direct to his bedroom, and had a handkerchief placed between his shoulders, beneath his shirt. In a few minutes after having been left alone, a singular noise, mingled with cries, was heard from his room; and when the people of the house rushed in, they found him on the floor, surrounded by a lambent flame. When visited next morning by Joseph Battaglia, a surgeon of Ponte Basco, the body was found much burned; he lingered in great pain for four days, when he died. The details of this case appeared at the time in the German periodicals.

Another instance, worthy of notice, and the authenticity of which may be relied on, is the following. Anne Nelis, wife of a wine and spirit merchant living in South Frederick street Dublin, let in her husband, who had been out at a party, between twelve and one o'clock on a Saturday night. After some altercation having taken place between them, both being in a state of intoxication, Mr. Nelis went up stairs to bed, but in a few minutes came down to request his wife to accompany him, an invitation which she positively declined, upon which he

took with him her candle, observing, that if she was resolved to sit up, she should do so in the dark. Next morning the servant girl having opened the windows of the back parlour, observed something in the chair in which her mistress usually sat, which she imagined at first sight to have been put there by young Nelis, who at the instant entered the room, for the purpose of frightening her. Upon examination, however, it turned out to be the remains of Mrs. Nelis, which were found in the following state. She was seated in a chair at a distance from the fire, which appeared to have burned out, with the head leaning upon the right hand, and bearing behind against the wall. The trunk of the body was burned to a cinder, as also the clothes which invested it; but the region of the pelvis, and the upper and lower extremities of the body had sustained no injury. Her face had a scorched appearance; but her hair and the papers she had put in it, had escaped. The back and seat of the chair had not suffered, but its arms were charred on the inner side, were in contact with the body. With the exception of the arms of the chair, the surrounding bodies were not injured by the combustion. The room was filled with a penetrating and disagreeable odour, which lasted many days.

Mr. Wood, a Wesleyan clergyman, residing in Limerick, relates the following case in the Methodists' Magazine for 1809. Mr. O'Neil, keeper of the Five Pounds Alms-house in the city of Limerick, was awakened about two in the morning by a person knocking at his door, upon which he rose, and having enquired who knocked, he opened the door, and going with the person who called him into his apartment, which lay under Mrs. Peacock's room, he found a dead body lying on the ground burning with fire, and red as copper, having dropped down from the loft; he saw a large hole, the size of the dead body, burned through the boards and ceiling. He instantly ran up stairs, and having broken open Mrs. Peacock's room door, saw in the middle of the room the burned hole through which the body had fallen. Having with assistance quenched the fire about the hole, he examined by what means the body had taken fire, but could find no cause. There was no candle or candlestick near the place; no fire in the grate but what was raked in the ashes, as is

the manner of preserving fire by night; the room was examined, and nothing had taken fire but that part of the floor, through which she had fallen; even a small basket made of twigs, and a small trunk of dry wood which lay near the hole, escaped, and were not so much as touched by the fire.

Here, likewise, we shall add another case, on apparently good authority. Mrs. Stout, widow of a watch-maker, and married a second time to a man of the name of Hanna, went to bed one evening in apparent health, and was found next morning burnt to a cinder, lying on the floor of her bedroom. When discovered, a vapour was still issuing from her mouth and nostrils, and those parts of the body, the form of which had not been altered. Her chemise and nightcap remained uninjured. This case occurred in 1808, at a place called Coote Hill, in the county of Cavan. The subject was a woman about sixty years of age, and an inveterate drunkard.

The Rev. Mr. Ferguson, of Camden street, Dublin, has attested the following facts: a woman, about sixty years of age, who lived with her brother, in the county of Down, retired one evening to bed with her daughter, both being, as was their constant habit, in a state of intoxication. A little before day, some members of the family were awakened by an extremely offensive smoke which pervaded their apartment, and, on going into the chamber where the old woman and her daughter slept, they found the smoke to proceed from the body of the former, which appeared to be burning with an internal fire. It was as black as coal, and the smoke issued from every part of it. The combustion having been arrested, which was effected with difficulty, life was found entirely extinct. Her daughter sustained no injury; nor did the combustion extend to the bed or bed-clothes, which exhibited no other traces of fire, than the stains produced by the smoke. According to the testimony of one of her relations, who is represented as a woman of the strictest veracity, there was no fire whatever in the room.

We could easily lay before our readers the details of numerous similar cases that have occurred in Great Britain, France, and Germany; but we consider the fore-

going sufficient to show the curious and remarkable fact, that the human body is, in certain conditions, capable of generating a gas which, the moment it comes in contact with air, takes fire. This has happened hitherto generally to those who have been addicted to ardent spirits; that is, to such persons whose bodies have, from excessive drinking, become saturated with alcohol; and it is a well known fact, that, after death, the internal organs of such persons—even the brain—will give out the odour of spirits. The gas, which is thus formed, is a compound of hydrogen and phosphorus. Hydrogen is one of the principal constituents of water; and may, by the decomposition of water, be easily obtained. Now the human body contains a great quantity of water; and phosphorus also, in a certain combination with earthy matter, enters into the composition of bones, and other solids of the body. This being premised, it is not difficult to understand, how, in certain cases, the phosphorus may be set free, so as to enter into combination with the hydrogen, producing this inflammable gas. Hence it is not necessary to apply a spark, or flame to the body, which becomes so ignited; and only those parts may be destroyed which present the requisite proportion of phosphorus: accordingly the clothes of such persons are not destroyed, nor does water put out the flame; because the water contains hydrogen, and being immediately decomposed, its hydrogen unites with an additional proportion of phosphorus, and so renews the gas which thus spontaneously inflames. D'Azyr, Lecat, Lair, Kopp, and Marc, have, with many other celebrated men, paid particular attention to the phenomena exhibited during spontaneous destruction by fire of the human body. M. de Fontenelle lately read a paper to the French Academy, in which he draws the following general conclusions:—

1. Spontaneous combustion generally happens to those who are habitual drinkers.

2. Old women are most subject to this calamity.

3. The combustion is usually general, but sometimes very partial, the feet, hands, and the top of the head, are generally the only parts that have been preserved.

This kind of burning does not inflame the most combustible substances.

5. Water, instead of diminishing, increases the flame.

Such are the general facts which have been established on this interesting subject; and the moral we wish to draw from their detail is simply this—that we should hesitate before we dogmatically assert any thing to be false, because it does not accord with our own experience; for the progress of sciences with which we are at present unacquainted, may explain on the most simple principles, the very facts which appear to us the most startling and incredible.

ATTRACTION.

THIS word betokens that power by which all kinds of matter, whether of the size of atoms or of worlds, are drawn towards each other. Perhaps, there is no law of nature which produces phenomena so universally and continually presented to our observation as attraction. If we lift our eyes to the starry heavens, and observe the "mystic dance" of these shining orbs, we find it, like an invisible rein curbing them in their amazing journeys through the trackless ether, and compelling them to deviate from the straight forward course in which they would otherwise run, and wheel in a circular manner round some other body, the centre of their orbits of motion. Or if we turn our attention to the globe we inhabit, we find it drawing down to the earth the stone which we have thrown into the air, or we see it forming into a globule the little drop of dew which hangs like an appropriate gem upon the delicate leaf of a flower. Or we see two contiguous drops upon the same spray, when brought near to each other, but still situated at a distance sufficient to be discerned by the eye, at last rush suddenly together and become one. Or we may detect its operations in uniting a few simple substances in various proportions, and producing the wonders of vegetable organization in infinite variety and never-failing sympathy! How sublime, yet how simple; how minute, yet how comprehensive and magnificent is this law! at once exercising a power over the smallest atoms around us, while it is, at the same time, determining the revolutions of the gigantic and innumerable orbs that roll throughout the universe; a height and a depth, a breadth and a length of existence, which imagination, in vain, attempts to picture, or reason to calculate. Or, as Rogers justly observes:—

> "That very law which moulds a tear
> And bids it trickle from its source,
> That law preserves the earth a sphere,
> And guides the planets in their course."

This law is indispensable for the preservation and existence of the present order of things; and it would not be difficult to show, that the suspension of it, even with respect to a single star, would in course of time, spread disorder and anarchy throughout the universe. But its invariable operation is the certainty of destiny. Without this unchangeableness philosophy would only be a doctrine of chances; but eclipses for thousands of years to come, for instance, (supposing our world was to remain for so long,) can be calculated upon without fear of mistake, almost to the beat of a watch.

The subject of attraction naturally separates itself into two grand divisions. There is first, the attraction which is exercised by masses of matter, situated at sensible distances from each other; and secondly, the attraction existing amongst the atoms constituting these masses, which takes place at insensible distances. These two divisions are again subdivided, the former into the attractions of gravitation, electricity, and magnetism; and the latter into those of aggregation or cohesion, and chemical attraction or affinity. Many philosophers have supposed, and with some degree of plausibility, that all these varieties depend upon some ultimate power of matter, and may thus be reduced into one; yet as no conclusive argument has been brought forward in support of this supposition, it is needless to take up the time of the reader with ideal speculations, even allowing that they may be correct.

By gravitation is meant that power which draws the objects of the universe towards each other. The sublime genius of Newton, it is said, conceived the idea of universal attraction, from the simple incident of an apple falling from a tree in his garden. May not, he reasoned, the power which draws this apple to the ground with unerring certainty, be the same as that which regulates the movements of the celestial systems. And so, following up this idea, he made a series of discoveries the most brilliant that ever adorned the annals of philosophy. He proved satisfactorily that what we term *weight* is nothing more than an instance of universal attraction, which decreases in intensity as we recede from the earth in distance. This, of course, suggested the idea that weight must be less on the tops of mountains, and in balloons,

than on the sea shore, or on plains, which is the fact. What weighs 1000 pounds on the sea shore, weighs 5 pounds less at the tops of mountains of a certain height, as is proved experimentally by a spring-balance; and at the distance of the moon, the weight or attraction towards the earth of 1000 pounds is diminished to 5 ounces. This has been proved by astronomical tests.

It may be necessary, however, before proceeding farther, to inform the reader of the manner in which gravitation operates on its amplest scale in regulating the movements of the unnumbered orbs which compose the system of the universe. All bodies have a tendency to continue in the state of *motion* or of *rest* in which they are put. In other words, bodies do not acquire motion, nor lose motion, nor change the kind or degree of their motion, unless some force or another be applied to them. This property, as it may be termed, is called in scientific language, the *inertia* of matter. For instance, when an arrow is shot from a bow, it would proceed onward through the infinity of space to all eternity, if some force did not curb its speed, and finally draw it to the earth. And what power is this? Plainly, that of attraction. Besides, there is the resistance which the air offers to every body heavier than itself passing through it. Now, space originally was a vast vacuity, we shall suppose, in which there being no matter, there could exist none of the laws of matter. When the Divine Creator brought into existence our own system, to take a familiar instance, he placed the sun in the centre, and endowed it, so to speak, with power and authority over all the other bodies within its range; they were compelled to pay obeisance to it like the surrounding sheaves to the one in Joseph's dream. The lesser or subordinate orb, may be supposed, for the sake of illustration, to have been hurled from the plastic hands of the Deity in a straightforward course, in which they would for ever have moved had not the sun possessed the power of attracting them to its centre and compelling them to revolve round him. There was just as much attraction given as would keep them in their proper orbits of motion, and just that degree of impetus imparted which would prevent them from coalescing with the sun on the one hand, or departing beyond the sphere of his attraction on the other. With what wisdom, yet

with what simplicity, have not the "worlds been framed." To each of them the Creator has traced out its course. "Thus far shalt thou go and no farther." And they cannot for a moment cross the boundaries he has assigned.

> "Lightnings and storms his mighty word obey,
> And planets roll where he has marked the way."

To this principle we are also indebted for the flux and reflux of the tides, which, as is well known, are caused by the moon's attraction.

> "For this moon through heaven's blue concave glides,
> And into motion charms the expanding tides;
> While earth impetuous round her axle rolls,
> Exalts her watery zone, and sinks the poles."

It is also the cause of the roundness of our earth, of the moon, the planets, and the sun itself. Hence it may be inferred that originally all matter was, to a certain extent, in a fluid state, and that at the divine command the atoms were endowed with attractive qualities, by which they were impelled to a common centre; and thus the congregated masses assumed a globular form. At New South Wales, which is situated nearly opposite to England on the earth's surface, planets hang and stones fall towards the centre of the globe just as they do here. And the people there are standing with their feet towards us; hence they are called our antipodes. A plummet suspended near the side of a mountain will be attracted to it in a degree exactly proportioned to its magnitude. This fact was acertained by Dr. Maskeleyne, near the mountain Shehallion, in Scotland. But the plummet was not so strongly attracted to the mountain as it was to the earth, because the magnitude of the latter was so much greater than that of the former. Let it always be kept in view that it is size, in connection with distance, which determines the force of gravitation, and this may be illustrated by a few familiar facts.

A falling body receives fresh velocity every moment of its descent, while a body projected into the air loses velocity every moment of its ascent. Both propositions are illustrated by a very simple experiment. Sling a stone into the air and the eye will be found incapable of

following it till it has reached a certain height, when we can easily observe its progress. Upwards it rises slower and slower, and for a moment before it has reached, and after it has passed, its climax, there is scarcely any motion perceptible; just as the tide at the full appears for a moment neither to ebb nor flow. Downwards the stone descends, however, gathering fresh velocity in every inch of its declination, until, as it approaches nearer to the earth, the eye can scarcely follow it. This may, no doubt, be partly accounted for from the well known circumstance, that, to the eye, bodies seen at a distance seem to move slower than they do when we stand near to them. But, in our calculations, the fallacy arising from this circumstance is comparatively trifling. The propositions have not only been proved by the most incontestible philosophical experiments, but a few familiar facts, when recalled to memory, will settle the point. Let a ball drop from the hand, and it can be caught easily the first instant; let it accumulate its motion, however, and the hand in vain pursues it. Take an example on a larger scale—say, the cataract of Niagara. Slow and heavily the broad column of water bends over the precipice. It grows thinner and thinner, while its motion rapidly increases, until at last it plunges down the deep descent into the boiling gulf below with irresistible force and rapidity, carrying all before it, and

"Rivalling the lightning's glance in ruin and in speed."

All bodies, whatever their size or weight may be, should, from the law previously laid down, fall to the ground with the same speed. But this is found not to be the case. Here, for instance, is a ball of lead and a ball of cotton dropped from the same height at the same moment, and the lead has reached the earth some time before the cotton. At first sight this would really appear to be quite consistent with the law of nature; because there being, we shall say, a hundred parts more matter in the lead than in the cotton, it will be drawn to the earth with a hundred times more force, the power of gravitation being always proportionate to the quantity of matter. But again, if there be a hundred parts more matter in the bullet than in the other body, it of course requires a hundred times

more attraction to bring it down, for bodies destitute of this quality, as has been frequently observed, have no tendency to fall: and every atom of every description of matter is drawn to the earth with the same degree of force. What is it, then, which prevents the cotton from reaching the ground at the same moment with the weightier body? The resistance of the air. The bulks are equal, and of course the resistance offered to both is alike, but the one having a far greater number of atoms, and hence a far greater power of attraction in proportion to its bulk than the other, it overcomes the resistance with greater ease, or, in other words, it has far greater strength to expend with only the same obstructions to overcome, and hence it reaches its destination sooner. For illustration's sake, let us suppose there are two boats to start for the same goal. They are of equal size, and of course their bows present the same breadth of surface to the water, and are alike impeded by it. In the one boat there are two rowers, we shall suppose, and in the other six. They all pull with equal skill and power, and it is unnecessary to say which boat will reach its destination first. But suppose the boat which had the smallest number of rowers were to be reduced in size, weight, and resistance in a proportion which exactly counterbalanced the power which the other had over it, they would both arrive at the same time. Thus, if the cotton ball was reduced to the density of the lead, they would both reach the earth at the same time. The powers of attraction possessed by the two substances, without attenuating our simile to an invisible thinness, may be compared to the physical energy exercised in the two several boats, and though the comparison be not perfect in some respects, it is sufficiently so in others to give a forcible illustration of the subject. In fine, it is found that in the exhausted receiver of an air-pump, that is, a glass vessel deprived of its air, a feather and a guinea fall to the bottom at the same instant. It would not serve the end contemplated, were the subject of gravitation to be pursued through all its labyrinths, and demonstrated by mathematical symbols. The point aimed at is rather to awaken a desire for philosophical study, than altogether to supply the materials of it.

Very little need be said here respecting the *magnetic*

and *electric* attractions, as they are more fully discussed under the titles *Magnetism* and *Electricity* in another part of this volume. They act on certain bodies, or under peculiar circumstances, giving rise to a distinct class of phenomena. In so far as they operate on masses of matter at sensible distances, they coincide with gravitation. When certain bodies are submitted to friction they exhibit electrical attraction. If a dry glass rod or a stick of sealing wax is rubbed upon a piece of silk, and then presented to light bodies, such as bits of paper or straw, these latter are attracted to the other body. With respect to the magnet, it is universally known that it possesses the property of attracting steel. Its undeviating tendency to turn to a certain point of the earth is also well known. No phenomena of nature has been so frequently pressed into the service of poetry in the shape of a simile than this. What poet for the last two hundred years has not used it?

> "The obedient steel with living instinct moves,
> And veers for ever to the pole it loves."

It is unnecessary to enter more particularly into these subjects at present, for the reason given above.

We shall now turn to the other grand division of the subject, namely, the attraction exercised between particles of matter situated at short or insensible distances from each other. Cohesive attraction is that power which retains atoms of the same kind together in masses. When two drops of the same sort of liquid are placed near to each other, as was remarked at the beginning of this article, they attract each other, and uniting together, form one globule. The roundness of the drop is caused by this attraction. The poet Drummond remarks this:—

> "Hast thou not seen two pearls of dew
> The rose's velvet leaf adorn—
> How eager their attraction grew,
> As nearer to each other borne."

If two globules of quicksilver on a smooth surface be brought near to each other, they will unite in a similar manner. They have also a tendency to remain in that state,

and will not separate until some force be applied. Cohesion is strongest in solids. For instance, a bar of iron of half an inch in diameter, or even less, will defy all our efforts to break it with the hand. In fluids the power is a great deal weaker as is proved by the ease with which we can separate one portion of water from another Small needles, however, can be made to float on water, their weight not being sufficient to overcome the cohesion of the fluid. In the same way small insects walk on the surface of water without being wetted. In gaseous bodies, such as air, this attraction is entirely overcome, and a mutual repulsion exists amongst the particles, which is the cause of their elasticity. Cohesion is illustrated by the following facts:—When portions of the same size are cut from two leaden bullets, and the fresh surfaces being brought into contact, and slightly pressed, they will unite, and appear as if they had been originally cast in one piece. Fresh cut surfaces of India-rubber cohere in a similar manner. There is a species of attraction called *adhesive* attraction, instances of which come frequently under observation. If water be poured from a jug which has not a projecting lip, it will not fall perpendicularly, but run down the outside of the vessel. Hence the reason of having a spout to such utensils. A plate of glass, when brought into contact with a level surface of water, adheres to it with considerable tenacity, and resists a separation. Pieces of wood floating in a pond attract each other, and remain in contact, and the wrecks of vessels, when the sea is smooth, are often found gathered together in heaps.

There is a species of attraction called *capillary*, which takes place under the following circumstances:—when one end of an open glass tube is put into the water, the enclosed liquid stands above the level of that on the outside, and it rises always the higher the smaller the bore of the tube is; the surrounding glass, being thus nearer to the water, attracts it more powerfully. A piece of lump sugar, whose lowest corner touches the water, soon becomes moistened throughout. Thus also the wick of a lamp or candle draws up the oil or tallow to supply combustion. The sap which rises from the roots to the tops of vegetables, though chiefly an action

of vegetable life, partly depends on capillary attraction for its ascent.

We come now to a most important and interesting part of the subject—*chemical attraction* or *affinity.* (See also article Chemistry in another part of this work.)

There are in nature about fifty-four substances which are termed elements, from the impossibility of human skill or industry to reduce them to any thing simpler. These elements, uniting together by the power of chemical attraction, form the infinite variety of objects around us. The investigation of this subject, from its great extent and importance, prevents us doing more in this place than giving a general idea of it, sufficiently attractive to induce the reader to feel interested in the science of chemistry, which will well repay a lengthened study of that important branch of scientific knowledge.

Chemical attraction is exercised between particles of dissimilar bodies, which uniting, form a new substance, possessing properties different from those of its ingredients. Frequently, indeed, the qualities of the compound are exactly the opposite of its constituents, as in the case of water. This liquid is composed of hydrogen, one of the most inflammable bodies known, and oxygen, the grand supporter of combustion on the globe. Yet when these are united, they form a fluid possessing qualities so totally different from their own, that it destroys all flame whatsoever; unless, indeed, the heat be so intense as to decompose the water; and frequently the same component parts when united in different proportions, produce the most opposite substances. Thus the common air that we breathe, is composed of the very same elements as aqua fortis. All bodies have not a chemical attraction for each other. Thus oil and water, though shaken together, will not unite; but if lime water is employed, a union takes place, and the result is a new compound which is insoluble in water. Again sulphuric acid, or vitriol, will not dissolve or unite with gold; but it will with copper or iron, (besides a great variety of other bodies) forming in the first instance sulphate of copper or blue vitriol; and in the second, sulphate of iron or copperas. Common sea sand and soda when heated, attract each other, and combining, form glass. What are called acids and alkalies have a strong affinity for each other,

and their compounds form a class of substances called salts, which are most important in the arts and manufactures. Oil of vitriol and soda, for instance, combine with great facility, and the compound is Glauber salts.

Thus by the existence and exercise of this peculiar property of matter, are formed the endless diversity of substances which constitute the mass of our globe. It is impossible to contemplate the subject of attraction in general, without a feeling of religious reverence and awe for the Divine Being who drew the mighty plan—set it in motion at first, and still upholds it. But the wisdom of it is not more conspicuous than the benevolence. Indeed, the operations of all the various laws of nature are to man so many sources of enjoyment. He stands, as it were, the centre of the system of life and nature around him. What attraction is in the abstract, human sagacity has not yet, and probably never will, unravel. The chain of cause and effect here breaks off, or rather for the present may be said to terminate, in the Deity. Philosophers may, however, discover a proximate cause, and even trace the golden links through a thousand beautiful windings, but in a Divine Creator they must merge at last.

ASTRONOMY.

THE EARTH'S MOTION.

We shall commence this article by selecting that portion which is most interesting to us, the earth; and after endeavouring to form a distinct idea of the part which it performs in the general system, proceed from thence to form some conception of the grandeur and immensity of the universe. Let us suppose the earth at its creation to have been projected forwards into universal space. We know that if no obstacle impeded its course, it would proceed in the same direction, and with a uniform velocity for ever; but the attraction of the sun stopped its onward progress, and confines it to a centre. It then commenced a course which it has pursued ever since it first issued from the hand of its Creator, and which there is every reason to suppose it will follow as long as it remains in existence. The earth travels round the sun, not in a circle, but an ellipsis, of which the sun occupies one of the *foci*; and in its course the earth alternately approaches and recedes from it; so that what at first appears to be a dangerous irregularity, is the means by which the most perfect order and harmony are produced. The earth then travels on at a very unequal rate, its velocity being accelerated as it approaches the sun, and retarded as it recedes from it.

The part of the earth's orbit nearest the sun is called its *perihelion*, that part most distant from the sun its *aphelion;* and the earth is about three millions of miles nearer the sun at its perihelion than at its aphelion. The reader will be surprised to learn that during the height of our summer, the earth is in that part of its orbit which is most distant from the sun, and it is during the severity of winter that it approaches nearest to it. The

difference, however, of the earth's distance from the sun in summer and winter, when compared with its total distance from the sun, is but inconsiderable, for three millions of miles sinks into insignificance when compared with ninety-five millions, which is our mean distance from the sun. The change of temperature arising f.om this difference, would in itself scarcely be sensible, and it is completely overpowered by other causes which produce the variations of the seasons; but the explanation of these must be deferred till we have made some farther observations on the heavenly bodies. Since the earth moves with the greatest velocity in that part of its orbit nearest the sun, it must complete its journey through one half of its orbit in a shorter time than through the other half; and, in fact, it is about seven days longer in performing our summer half of its orbit than the winter half. The planets are celestial bodies which revolve round the sun, on the same principle, and they are supposed to resemble the earth also in many other respects; and we are led by analogy to consider them as inhabited worlds.

Some of the planets are proved to be larger than the earth; it is only their immense distance from us which renders their apparent dimensions so small. Now, if we consider them as enormous globes, instead of small twinkling spots, we shall find it most consistent with our ideas of the Divine wisdom and beneficence, to suppose that these celestial bodies should be created for the habitation of beings who are, like us, blessed by his Providence. Hence, in a moral, as well as a physical point of view, it is most rational to consider the planets as worlds revolving round the sun; and the fixed stars as other suns, each of them probably attended by its system of planets, to which they respectively impart their influence. Our telescopes are brought to such a degree of perfection, that from the appearances which the moon exhibits when seen through them, we have probable reason to conclude that it is a habitable globe; its mountains and valleys are very perceptible, and some astronomers have even imagined that they saw volcanoes in it.

The planets which are supposed to revolve round the fixed stars must of course be much smaller than the suns which give them light; and the distance which makes

these suns appear to us like stars must render their planets quite invisible: besides, the light of these planets would be much more feeble than that of the fixed stars; there would be exactly the same sort of difference as between the light of the sun and that of the moon, the first being a fixed star, the second a planet.

According to the laws of attraction, the planets belonging to our system, all gravitate towards the sun; and this force, combined with that of projection, occasion their revolution round the sun, in orbits more or less elliptical, according to the proportion which these two forces bear to each other. But the planets have also another motion: they revolve upon their axis. The axis of a planet is an imaginary line which passes through its centre, and on which it turns; and it is this motion which produces day and night. With that side facing the sun, it is day; and with the opposite side which remains in darkness, it is night. Our earth, which we consider as a planet, is twenty-four hours in performing one revolution on its axis; in that period of time therefore we have a day and a night. Hence this revolution is called the earth's diurnal or daily motion; and it is this revolution of the earth from west to east which produces an apparent motion of the sun, moon, and stars in the contrary direction.

THE PLANETS.

The planets are distinguished into primary and secondary. Those which revolve immediately about the sun are called primary. Many of these are attended in their course by smaller planets, which revolve round them; these are called secondary planets, satellites, or moons. Such is our moon, which accompanies the earth, and is carried with it round the sun. The sun is the general centre of attraction to our system of planets; but the satellites revolve round the primary planets, on account of their greater proximity. The force of attraction is not only proportional to the quan-

tity of matter, but to the degree of proximity of the attracting body. This power being weakened by diffusion, diminishes as the squares of the distance increase. The square is the product of a number multiplied by itself; so that a planet situated at twice the distance at which we are from the sun would gravitate four times less than we do, the product of two being multiplied by itself being four. The more distant planets, therefore, move slower in their orbits; for their projectible force must be proportioned to that of attraction. This diminution of attraction by the increase of distance also accounts for motion of the secondary round the primary planets, in preference to the sun; for the vicinity of the primary planets renders their attraction stronger than that of the sun. But since the attraction between bodies is mutual, the primary planets are also attracted by their satellites. The moon attracts the earth, as well as the earth the moon, but as the latter is the smaller body, her attraction is proportionally less. The result is, that neither the earth revolves round the moon, nor the moon round the earth: but they both revolve round a point which is their common centre of gravity, and which is as much nearer the earth than the moon, as the weight of the former exceeds that of the latter. If two bodies are fastened together by a wire or bear, their common centre of gravity will be in the middle of the bar, provided the bodies are of equal weight; and if they differ in weight, then it will be nearer the larger body. Attraction is the tie which unites the earth and moon; and if these bodies had no projectile force which prevented their mutual ttraction rom bringing them together, they would eet at their common centre of gravity.

The earth, then, has three different motions; it revolves round the sun, upon its axis, and around the point towards which the moon attracts it; and this is the case with every planet which is attracted by satellities. The complicated effect of this variety of motions produces irregularities, which, however, it is not necessary to notice at present. The planets act on the sun in the same manner as they are themselves acted on by their satellities; but the gravity of the planets (even when taken collectively) is so trifling compared with that of the sun, that they do not cause the latter to move so much as one

half of its diameter. The planets do not, therefore, revolve round the centre of the sun but round a point, at a small distance from its centre, about which the sun also revolves. The sun also revolves on its axis. This motion is ascertained by orbserving certain spots which disappear and reappear regularly at stated times.

The great distance of the planets render their motions apparently so slow, that the eye is not sensible of their progress in their orbit, unless we watch them for some considerable length of time: in different seasons they appear in different parts of the heavens. The sun is the common centre of the whole.

Mercury is the planet nearest the sun: his orbit is consequently contained within ours; but his vicinity to the sun occasions his being nearly lost in the brilliancy of his rays; and when we see this planet, the sun is so dazzling, that very accurate observations cannot be made upon him. He performs his revolution round the sun in about eighty-seven days, which is consequently the length of his year; the time of his rotation on his axis is not accurately known; his distance from the sun is computed to be thirty-seven millions of miles, and his diameter 3224 miles. The heat of this planet is so great, that water cannot exist there but in a state of vapour, and metals would be liquified.

Venus, the next in the order of planets, is sixty-eight millions of miles from the sun; she revolves about her axis in twenty-three hours and twenty-one minutes, and goes round the sun in 224 days 17 hours. The diameter of Venus is 7687 miles. The orbit of Venus is within ours; during nearly one half of her course in it we see her before sunrise, and she is called the morning star; in the corresponding part of her orbit, on the other side, she rises later than the sun. We then cannot see her rising, as she rises in the day time; but she also sets later, so that we perceive her approaching the horizon after sunset: she is then called Hesperus, or the evening star.

The planet next to Venus, is the Earth, of which we shall soon speak at length; at present we shall only observe, that we are ninety-five millions of miles distant from the sun—that we perform our annual revolution in 365 days 5 hours and 49 minutes—and are attended in our course by a single moon.

Then follows Mars. He can never come between us and the sun like Mercury, and Venus; his motion, however, is very perceptible, as he may be traced to different situations in the heavens; his distance from the sun is 144 millions of miles; he turns on his axis in twenty-four hours and thirty-nine minutes, and he performs his annual revolution in about 687 of our days; his diameter is 4,189 miles. Then follow four very small planets—Juno, Ceres, Pallas, and Vesta, which have been recently discovered, but whose dimensions and distances from the sun have not as yet been very accurately ascertained.

Jupiter is next in order. This is the largest of all the planets; he is about 490 millions of miles distant from the sun, and completes his annual period in nearly twelve of our years; he revolves upon his axis in about ten hours; he is about 1,400 times as large as our earth, his diameter being 89,170 miles. He is attended by four moons.

The next planet is Saturn, whose distance from the sun is about 900 million of miles. His diurnal rotation is performed in about ten hours and a quarter; his annual revolution is nearly thirty of our years; his diameter is 79,000 miles. This planet is surrounded by a luminous ring, the nature of which astronomers are much at a loss to conjecture: he has seven moons.

Lastly, we observe the Georgium Sidus, discovered by Dr. Herschel, and which is attended by six moons. His numerous moons are, however, far from making so splendid an appearance as ours; for they can only reflect the light which they receive from the sun; and both light and heat decrease in the same ratio or proportion to the distances as gravity;—consequently, Saturn, which is nearly ten times the distance at which we are from the sun, has an hundred times less heat and light. To us such a climate would not be habitable; but this furnishes no argument against the supposition that these planets are worlds, peopled with beings whose bodies are adapted to the various temperatures and elements in which they are situated. Whether we judge from the analogy of our own earth, or from that of the great and universal beneficence of Providence, we may readily conjecture this to be the case: and an inhabitant of Mercury might with as much plausibility pity us for the intense

coldness of our situation, or those of Jupiter and Saturn for our intolerable heat, as we can draw any inferences against their existence, from the circumstance that we, constituted as we are, could not live there.

Comets are supposed to be planets. The re-appearance of some of them proves that they revolve around the sun; but in orbits so extremely eccentric, and running to such a distance from the sun, that they disappear for a great number of years. If they are inhabited it must be by a species of beings very different, not only from the inhabitants of this, but from that of any of the other planets; as they must experience the greatest vicissitudes of heat and cold; their heat in that part of their orbit nearest to the sun is computed to be greater than red hot iron. In this part of its orbit the comet emits a luminous vapour, called the tail, which it gradually loses as it recedes from the sun; and the comet itself totally disappears from our sight in the more distant parts of its orbit, which, in most cases, extends considerably beyond that of the farthest planet. The number of comets belonging to our system cannot be ascertained, as some of them are several centuries before they make their re-appearance. The number that are known by their regular re-appearance is very small.

The ancients, in order to recognize the fixed stars, formed them into groups, to which they gave the name of the figures delineated on the celestial globes. In order to show their proper situations in the heavens they should be painted on the internal surface of a hollow sphere, from the centre of which they should be viewed: they would then be seen as they appear in the heavens. The twelve constellations called the signs of the Zodaic, are those which are so situated, that the earth in its annual revolution passes directly between them and the sun. Their names are, Aries, the Ram; Taurus, the Bull; Gemini, the Twins; Cancer, the Crab; Leo, the Lion; Virgo, the Virgin; Libra, the Balance; Scorpio, the Scorpion; Sagittarius, the Archer; Capricornus, the Wild Goat; Aquarius, the Water carrier; Pisces, the Fishes; the whole occupying a complete circle, or broad belt, in the heavens, called the Zodiac. Hence, a line drawn from the earth, and passing through the sun, is

said to be in that constellation at which the line terminates.

The perfection of astronomical instruments has afforded the prospect of being able to determine the annual Parallax, and consequently the distance of the fixed stars; but the quantity of deviation is so small as to have hitherto eluded the closest observation. It cannot amount to a single second in the most conspicuous, and probably the nearest of the stars. These luminous bodies must therefore be more distant at two hundred thousand times than the measure of the diameter of the earth. The light emitted from such neighbouring suns, though it flies with incredible rapidity, must yet travel more than six thousand years before it reaches the confines of our system. But scattered over the immensity of space, there may exist bodies which, by their magnitude and predominant attraction, retain or recal the rays of light, and are lost in solitude and darkness. Had the celerity of the luminous particles not exceeded four hundred miles in a second, we should never have enjoyed the cheering beams of the sun. They would have been arrested in their journey, and drawn back to their source before they reached the orbit of Mercury. But a star similar to our sun, and having a diameter sixty-three times greater, would entirely overpower the impetus of light.

Whether the apparent difference of size and brilliancy of the stars proceed from their various degrees of remoteness, or of dimension, is a point which astronomers are unable to ascertain. Considering them as suns, we know no reason why they should not vary in size, as well as the planets belonging to them.

It may perhaps be objected to this system of the universe, that it is directly in opposition to the evidence of our senses, to which it is plain and obvious that the earth is motionless, and that the sun and stars revolve round it. But our senses, or at least the inferences we draw from them, too often mislead us, for us to place implicit reliance on them. When sailing on the water with a very steady breeze, the houses, trees, and every object appear to move, whilst we are insensible of the motion of the vessel in which we sail. It is only when some obstacle impedes our motion that we are conscious of

moving; and were you to close your eyes while sailing on calm water, with a steady wind, you would not perceive that you moved, for you could not feel it, and you could see it only by observing the change of place of the objects on shore. So it is with the motion of the earth: every thing on its surface, and the air that surrounds it, accompanies it in its revolution—it meets with no resistance, therefore we are insensible of motion.

The apparent motion of the sun and stars affords us the same proof of the earth's motion, that the crew of a vessel has of their motion from the apparent motion of the objects on shore. Imagine the earth to be sailing round its axis, and successively passing by every star, which, like the objects on land, we suppose to be moving, instead of ourselves. In baloons, the earth appears to sink beneath the baloon, instead of the baloon rising above the earth.

It is a law which we discover throughout Nature, and worthy of its great Author, that all its purposes are accomplished by the most simple means. We have no reason to suppose this law infringed in order that our earth may remain at rest, while the sun and stars move round us. their regular motions, which are explained by the laws of attraction, on the first supposition, would be unintelligible on the last, and the order and harmony of the universe be destroyed. What an immense circuit the sun and stars would make daily, were their apparent motions real! We know many of them to be bodies more considerable than our earth; for our eyes vainly endeavour to persuade us, that they are little brilliants sparkling in the heavens, while science teaches us that they are immense spheres, whose apparent dimensions are diminished by distance. If the heavenly bodies revolved round our earth in twenty-four hours, the centrifugal force implied in so rapid a motion would be quite destructive; and no power can be assigned which would be sufficient to balance it; grindstones driven by machinery in manufactories have been known to fly in pieces from their great velocity. Why then should these enormous globes traverse such an immensity of space, merely to prevent the necessity of our earth revolving on its axis? The motion produced by the revolution of the earth on its axis, is about thirteen miles and a half in a minute, to an inhabitant of London.

A person at the equator moves much quicker; and one situated near the poles much slower, since they each perform a revolution in twenty-four hours. But in performing its revolution round the sun, every part of the earth moves with an equal velocity, and this velocity is no less than a thousand miles a minute.

In ancient times the earth was supposed to occupy the centre of the system; and the sun, moon, and stars to revolve around it. This was the system of Ptolemy: but so long ago as the beginning of the sixteenth century it was discarded, and the solar system such as we have shown, was established by the celebrated astronomer Copernicus and his followers, and is hence called the Copernican system. But the theory of gravitation, the source whence this beautiful and harmonious arrangement flows, we owe to the powerful genius of Sir Isaac Newton, who lived at a much later period.

It is far less difficult to trace by observation the motion of the planets, than to divine by what power they are impelled and guided. The idea of gravitation, it is said, was first suggested to Sir Isaac Newton, by a circumstance from which one should little have expected so grand a theory to have arisen. During the prevalence of the plague in the year 1665, Newton retired into the country to avoid the contagion. When sitting one day in his orchard, he observed an apple fall from a tree, which led to a train of thought whence his grand theory of gravitation was ultimately developed. His first reflection was whether the apple would fall to the earth, if removed to a great distance from it; then, how far it would require to be removed from the earth, before it would cease to be attracted; would it retain its tendency to fall at the distance of a thousand miles, or ten thousand, or to the distance of the moon? And here the idea occurred to him, that it was not impossible the moon herself might have a similar tendency, and gravitate to the earth in the same manner as the bodies on or near its surface, and this gravity might possibly be in the power which balanced the centrifugal force implied in her power in her orbit. It was natural then to extend this idea to the other planets, and consider them as gravitating towards the sun, in the same manner as the moon gravitates towards the earth. He followed up this beau-

tiful hypothesis, by a series of calculations and demonstrations unparalleled for their originality, and the industry and judgment with which they were conducted, until he established the stupendous doctrine of universal gravitation! Who would imagine that the simple circumstance of the fall of an apple would have led to such magnificent results? It is the mark of superior genius to find matter for observation and research in circumstances which, to the ordinary mind, appear trivial, because they are common, and with which they are satisfied because they are natural, without reflecting that Nature is our grand field of observation—that within it is contained our whole store of knowledge: in a word, that to study the works of Nature, is to learn to appreciate and admire the wisdom of God. Thus it was the simple circumstance of the fall of an apple which led to the discovery of the laws upon which the Copernican system is founded; and whatever credit this system had obtained before, it now rests upon a basis from which it cannot be shaken.

THE EARTH.

In explaining the effects resulting from the earth's annual and diurnal motion, it is necessary that the reader should understand the terrestrial globe. This globe represents the earth. The line which passes through its centre, and on which it turns is the axis; and the two extremities of the axis are the poles, distinguished by the names of the north and south poles. The circle which divides the globe into two equal parts between the poles is called the equator or equinoctial line; that part of the globe to the north of the equator is the northern hemisphere; that part to the south of the equator, the southern hemisphere. The small circle, which surrounds the north pole, is called the arctic circle; that surrounding the south pole, the antarctic circle. There are two immediate circles between, the polar circles and the equator,—that to the north, called the tropic of Cancer; that to the south,

called the tropic of Capricorn. Lastly, this circle which divides the globe into two equal parts, crossing the equator, and extending northward as far as the tropic of Cancer, and southwards as far as the tropic of Capricorn, is called the ecliptic.

The spaces, between the several parallel circles on the terrestrial globe, are called zones; that which is comprehended between the tropics is distinguished by the name of the torrid zone; the spaces which extend from the tropics to the polar circles, the north and south temperate zones; and the space contained within the polar circles the frigid zones.

The several lines which are drawn from one pole to the other, cutting the equator at right angles, are called meridians. When any one of these meridians is exactly opposite the sun, it is mid-day, or twelve o'clock in the day, with all the places situated on that meridian; and with the places situated on the opposite meridian, it is consequently midnight. To places situated equally distant from these two meridians it is six o'clock. If they are to the east of the sun's meridian, it is six o'clock in the afternoon, because the sun will have previously passed over them; if to the west, it is six o'clock in the morning, and the sun will be proceeding towards that meridian.

Those circles which divide the globe into two equal parts, such as the equator and the ecliptic, are called great circles—to distinguish them from those which divide it into two unequal parts, as the tropics and polar circles, which are called small circles. All circles are divided into 360 equal parts called degrees; and these degrees into 60 equal parts called minutes.

Besides the usual division of circles into degrees, the ecliptic is divided into twelve equal parts, called signs, which bear the name of the constellations through which this circle passes in the heavens. The degrees measured on the meridians from north to south, or south to north, are called degrees of latitude; those measured from east to west on the equator, or any of the lesser circles parallel to it, are called degrees of longitude;—these circles are called parallels of latitude, because being every where at the same distance from the equator, the latitude of every point contained in any one of them is the same.

The degrees of longitude must necessarily vary in

length according to the dimensions of the circle on which they are reckoned, those, for instance, at the polar circles, will be considerably smaller than those at the equator. The degrees of latitude on the contrary, never vary in length, the meridians on which they are reckoned being all of the same dimensions. The length of a degree of latitude is 60 geographical miles, which is equal to 69½ English statute miles. The degrees of longitude at the equator would be of the same dimensions were the earth a perfect sphere, but its form is not exactly spherical, being somewhat protuberant about the equator, and flattened towards the poles. This form proceeds from the superior action of the centrifugal power at the equator. The revolution of the earth on its axis gives every particle a tendency to fly off from the centre. This tendency is stronger or weaker in proportion to the velocity with which the particle moves. Now a particle situated near one of the polar circles, makes one rotation in the same space of time as a particle at the equator, the latter therefore having a much larger circle to describe, travels proportionally faster, consequently the centrifugal force is much stronger at the equator than at the polar circles: it gradually decreases as you leave the equator and approach the poles, where, as there is no rotatory motion, it entirely ceases. Supposing therefore, the earth to have been originally in a fluid state, the particles in the torrid zone would recede much farther from the centre than those in the frigid zone; the polar regions would become flattened, and those about the equator elevated. According to the same rule, our heads move with greater velocity than our feet; and on the summit of a mountain, our velocity is greater than in a valley; for the head is more distant from the centre of motion than the feet—the mountain top than the valley, Even at the equator, however, the force of gravity preponderates very considerably, being at the equator two hundred and eighty eight times greater than the centrifugal force.

It would be natural to suppose that the prominence at the equator and depression at the poles would render the attraction of gravity stronger at the former, so that a body would weigh heavier at the equator than at the poles. This, however, is erroneous. The manner in which the force of gravity varies, at different spots on the

surface of the earth, depends on considerations too complicated to be here explained; but the general result is that, although the difference in different situations is very small, the nearer any part of the surface is to the centre of attraction, the more strongly it is attracted. We refer, however, only to any situation on the surface of the earth. Were you to penetrate into the interior, the attraction of the parts above you would counteract that of the parts beneath you, and consequently diminish the power of gravity in proportion as you approached the centre; and if you reached that point, being equally attracted by the parts all around you, gravity would cease, and you would be without weight. Bodies therefore gravitate less, and consequently weigh less, at the equator than at the poles, while their centrifugal force is much greater; and as this force tends to drive bodies from the centre, it is necessarily opposed to, and must decrease the power of gravity. There are then two causes which render bodies lighter in weight at the equator than at the poles—the diminution of gravitation, and the increase of the centrifugal force.

We shall now explain the variation of the seasons, and the difference of the length of the days and nights in those seasons—both effects resulting from the same cause. In moving round the sun, the axis of the earth is not perpendicular to the plane of its orbit; in other words, its axis does not move round the sun in an upright position, but slanting or oblique. In the midst of summer, the globe is situated at what is called the summer solstice, which is on the 21st of June. The north pole is then inclined towards the sun, and the northern hemisphere enjoys much more of its rays than the southern. The sun now shines over the whole of the north frigid zone; and notwithstanding the earth's diurnal revolution, it will continue to shine upon it as long as it remains in this situation, whilst the south frigid zone is at the same time completely in obscurity.

Let the earth now set off from its position in the summer solstice and carry it round the sun: observe that the axis must always be inclined in the same direction, and the north pole point to the same spot in the heavens. There is a fixed star situated near that spot—which is hence called the North Polar Star. The earth has now

gone through one quarter of its orbit, and is arrived at that point at which the ecliptic crosses the equator, and which is called the autumnal equinox. The sun now shines from one pole to another, as it would constantly do were the axis of the earth perpendicular to its orbit, the inclination of the axis being now neither towards the sun nor in the contrary direction. At this period of the year the days and nights are equal in every part of the earth, excepting at the very poles; but the next step she takes in his orbit involves the north pole in darkness, while it illumines that of the south. This change was gradually preparing as the earth moved from summer to autumn; the arctic circle begins to have short nights, which increase as the earth approaches the autumnal equinox; and the instant it passes that point, the long night of the north pole commences, and the south pole begins to enjoy the light of the sun. As the earth proceeds in its orbit, the days shorten and the nights lengthen throughout the northern hemisphere, until it arrives at the winter solstice, on the 21st of December, when the north frigid zone is entirely in darkness, and the southern enjoys uninterrupted daylight. Exactly half of the equator, it will be observed, is enlightened in every position, and consequently the day is there always equal to the night.

The inhabitants of the torrid zone, it may be observed, have much more heat than we have, as the sun's rays fall perpendicularly upon them, while they shine obliquely on the temperate, and almost horizontally on the frigid zone; for during their long day the sun moves round at no great elevation above their horizon without either rising or setting; the only observable difference is, that it is more elevated by a few degrees at midday than at midnight; but at the poles themselves, the sun travels round in the course of twenty-four hours nearly at the same elevation from the horizon, rising every day a very little higher from the vernal equinox till midsummer, and declining after that period till the autumnal equinox, when their long night begins.

To a person placed in the temperate zone, as we are in England, the sun's rays will shine neither so obliquely as at the poles, nor so vertically as at the equator; but will fall upon him more obliquely in autumn and winter than

in summer. Therefore, the inhabitants of the earth between the polar circles and the equator will not have merely one day and one night in the year, as happens at the poles; nor will they have equal days and equal nights, as at the equator; but their days and nights will vary in length at the different times of the year, according as their respective poles incline towards or from the sun, and the difference will be greater in proportion to their distance from the equator. During the other half of her orbit, the same effect takes place in the southern hemisphere, as what we have just remarked in the northern. When the earth arrives at the vernal equinox, where the ecliptic again cuts the equator, on the 22nd of March, she is situated with respect to the sun, exactly in the same position as in the autumnal equinox, excepting that it is now autumn in the southern hemisphere, whilst it is spring with us; for the half of the globe which is enlightened extends exactly from one pole to the other: the sun rises to the north pole and sets to the south pole. On the two days of the equinox the sun is visible at both poles; but only half of it is seen from either, the other half being concealed by the horizon.

The sun is nearly three of our days in rising and setting at the poles. About thirty hours, or rather more, before he reaches the exact period of the autumnal equinox, the upper edge or limb of the sun begins to be visible at the south pole; and it is there seen constantly travelling round the horizon, and gradually rising higher and higher till at the end of about sixty. hours, after revolving nearly 2½ times round the horizon, the whole of its orb is visible.

At the same moment that the edge of the sun becomes visible at the south pole, the same edge which appears as the lower limb at the north pole, begins to dip below the horizon; but the sun still continues visible, travelling round the horizon, more and more of it being hid, till at the end of sixty hours, it totally disappears, just at the same moment when it is fully seen at the south pole. As the earth proceeds towards summer, the days lengthen in the northern hemisphere, and shorten in the southern, till the earth reaches our summer solstice, which brings it again to the spot whence we first accompanied him.

The mind can find no object of contemplation more

sublime than the course of this magnificent globe impelled by the combined powers of projection and attraction to roll in one invariable course around the source of light and heat; and what can be more delightful than the beneficent effects of this vivifying power on its attendant planet? It is at once the grand principle which animates and fecundates Nature.

The sun's rays afford less heat when in an oblique direction than when perpendicular, because few of them fall upon an equal portion of the earth. This accounts for the greater heat of summer, as the sun shines less obliquely in summer than in winter. But there is also another reason why oblique rays give less heat than those which are perpendicular; the former have a greater portion of the atmosphere to traverse; and though it is true that the atmosphere is itself a transparent body, it does not admit the passage of the sun's rays quite freely; and besides, it is always loaded more or less with dense and foggy vapour, which the rays of the sun cannot easily penetrate; therefore the greater the quantity of atmosphere the sun's rays have to pass through in their way to the earth, the fewer of them will reach it.

The diminution of heat, morning and evening, is also owing to the greater obliquity of the sun's rays; and as such, they are affected by both the causes which have just been explained. The difficulty of passing through a foggy atmosphere is more particularly applicable to them, as mists and vapours are very prevalent about the time of sunrise and sunset. But the diminished obliquity of the sun's rays is not the sole cause of the heat of summer; the length of the days greatly conduces to it; for the longer the sun is above the horizon, the more heat he will communicate to the earth, and yet, though both the longest days, and the most perpendicular rays are on the 21st of June, the greatest heat prevails in July and August. To account for this, you must reflect, that those parts of the earth, which are once heated, retain the heat for a considerable length of time; and the additional quantity they receive occasions an elevation of temperature, although the days begin to shorten, and the sun's rays to fall more obliquely. For the same reason we have generally more heat at three o'clock in the afternoon

than at twelve when the sun is on the meridian. As long as the sun continues to communicate more heat than the earth parts with in a given time, so long the heat of the earth will increase, even though the rate at which it receives new heat from the sun is diminished.

There is one more observation to make relative to the earth's motion which is, that although we have but 365 days and nights in the year, she performs 366 complete revolutions on her axis; during that time. This is owing to the progressive motion of the earth in its orbit whilst it revolves on its axis: as it advances almost a degree westward in its orbit, in the same time that it completes a revolution eastward on its axis; it must revolve nearly one degree more, in order to bring the same meridian back to the sun. These small daily portions of rotation are each equal to the three hundred and sixty-fifth part of a circle, which at the end of the year amounts to one complete rotation. If the earth, then, had no other than its diurnal motion, we should have 366 days in the year; or rather we should have 366 days in the same period of time that we now have 365; for if we did not revolve round the sun, we should have no natural means of computing years.

In regard to time, we must add, that the earth's diurnal motion, on an inclined axis, together with its annual revolution in an elliptic orbit, occasions so much complication in its motion as to produce many irregularities: therefore true equal time cannot be measured by the sun. A clock which was always perfectly correct, would in some parts of the year be before the sun, and in other parts after it. There are but four periods in which the sun and a perfect clock would agree, which are, the 15th of April, the 16th of June, the 31st of August, and the 24th of December. The greatest difference between solar time and true time amounts to between fifteen and sixteen minutes. Tables of the equation of time are constructed for the purpose of pointing out and correcting these differences between solar time and equal or mean-time, which is the denomination given by astronomers to true time.

THE MOON.

Let us now turn our attention to the moon. This satellite revolves round the earth in the space of twenty-seven days, eight hours, in an orbit nearly coinciding with the plane of the earth's orbit, and accompanies us in our revolution round the sun. Her motion, therefore, is of a complicated nature; for as the earth advances in her orbit whilst the moon goes round her, the moon proceeds in a sort of progressive circle. There are also other circumstances which interfere with the simplicity and regularity of the moon's motion, but which are too intricate for us to notice in our limited space.

The moon always presents the same face to us, by which it is evident that she turns but once upon her axis while she performs a revolution round the earth; so that the inhabitants of the moon have but one day and one night in the course of a lunar month. Since we always see the same hemisphere of the moon, the inhabitants of that hemisphere alone can perceive the earth. One half of the moon, therefore, enjoys our light every night, while the other half has constantly nights of darkness; and we appear to the inhabitants of the moon under all the changes or phases which the moon exhibits to us.

When the moon is full, she is said to be in opposition; when a new moon, to be in conjunction with the sun. At each of these times, the sun, the moon, and the earth are in the same right line; but in the first case, the earth is between the sun and the moon; in the second, the moon is between the sun and the earth. An eclipse can take place only when the sun, moon, and earth are in a right line. When the moon passes between the sun and the earth, she intercepts his rays, or, in other words, casts a shadow on the earth: then the sun is eclipsed, and the daylight gives place to darkness, while the moon's shadow is passing over us. When, on the contrary, the earth is between the sun and the moon, it is we who intercept the sun's rays, and cast a shadow on

the moon: she then disappears from our view and is eclipsed.

Why then, it may be asked, have we not a solar and a lunar eclipse every month?

The planes of the orbits of the earth and the moon do not exactly coincide, but cross or intersect each other; and the moon generally passes on either one side or the other when she is in conjunction with, or in opposition to, the sun, and therefore does not intercept the sun's rays, or an eclipse; for this can take place only when the earth and moon are in conjunction near those parts of their orbits which cross each other (called the nodes of their orbits), because it is then only that they are both in the same plane and in a right line with the sun. A partial eclipse takes place when the moon, in passing by the earth, does not entirly escape her shadow. When the esclipse happens precisely at the nodes, they are not only total, but last for some length of time.

When the sun is eclipsed, the total darkness is confined to one particular part of the earth. The lunar eclipses, on the contrary, are visible from every part of the earth, where the moon is above the horizon.

When the moon eclipses the sun to us, the earth is eclipsed to the moon; for if the moon intercepts the sun's rays, and casts a shadow on us, we must necessarily disappear to the moon, but only partially—a black spot will appear to pass over the earth.

In the distant planets, few days elapse without an eclipse taking place; for among the number of the satellites, one or other of them is continually passing into the shadow of the planet, or between the planet and the sun. Astronomers are so well acquainted with the motion of the planets and their satellites, that they have calculated not only the eclipses of our moon, but those of Jupiter, with such perfect accuracy, that it has afforded a means of ascertaining the longitude. When, as on land, we know where we are situated, there is no difficulty in ascertaining the latitude or longitude of the place by referring to a map; but the question is, to find out our situation when we do not know where we are: for instance, at sea, interrupted in our course by storms, a map would afford no assistance in discovering where we were. The latitude may be found by taking the altitude of the pole:

that is to say, observing the number of degrees that it is elevated above the horizon, for the pole appears more elevated as we approach it, and less as we recede from it. It is true that the pole is not visible to us; but the north pole points constantly towards one particular part of the heavens, near which a star is situated, called the Polar Star. The altitude of the polar star is therefore nearly the same number of degrees as that of the pole; and as this star is visible in clear nights from every part of the northern hemisphere, it furnishes an easy mode of ascertaining the latitude in all that half of the world. The latitude may be more accurately determined by other observations, which may be made on the sun, or any of the fixed stars; the situation therefore, of a vessel at sea, with regard to north and south, is easily ascertained. The difficulty is respecting east and west—that is to say, its longitude. As there are no eastern poles from which we can reckon our distance, some particular spot must be fixed upon for that purpose. The English reckon from the meridian of Greenwich, where the Royal Observatory is situated; in French maps the longitude is reckoned from Paris.

The rotation of the earth on its axis in twenty-four hours, from west to east, occasions, as we have already seen, an apparent motion of the sun and stars in the contrary direction, and the sun appears to go round the earth in the space of twenty-four hours, passing over fifteen degrees, or a twenty-fourth part of the earth's circumference every hour, therefore, when it is twelve o'clock in London, it is one o'clock in any place situated fifteen degrees to the east of London, as the sun must have passed the meridian of that place an hour before he reaches that of London. For the same reason it is eleven o'clock to any place situated fifteen degrees to the west of London, as the sun will not come to that meridian till an hour later. If, then, the captain of a vessel at sea could know precisely what was the hour at London, by looking at his watch, and comparing it with the hour of the spot in which he was, ascertain the longitude. For this purpose he must be furnished with two watches—the one daily regulated by the sun, and the other unaltered. The former would indicate the hour of the place in which he was situated, and the latter the hour of London; and by com-

paring them together, he would be able to calculate his longitude; but the best watches are liable to imperfections, and should the time-keeper go too slow, there would be no means of ascertaining the error: implicit reliance, therefore, cannot be placed upon them.

Recourse is had therefore to the eclipses of Jupiter's satellites. A table is made of the precise time at which the several moons are eclipsed to a spectator at London. When they appear eclipsed to a spectator in any other spot, he may, by consulting the table, know what is the hour at London; for the eclipse is visible at the moment from whatever place on the earth it is seen. He has then only to look at the watch which points out the hour of the place in which he is, and by observing the difference of time there and at London, he may immediately determine his longitude.

Let us suppose that a certain moon of Jupiter is always eclipsed at six o'clock in the evening at London, and that a man at sea consults his watch and finds that it is ten o'clock at night, where he is situated, at the moment the eclipse takes place: he would be sixty degrees east of London; for the sun which (apparently) travels fifteen degrees an hour, must have passed his meridian four hours before it reaches that of London; for this reason the hour is always later in London when the place is east longitude, and earlier when it is west longitude. Thus the longitude can be ascertained whenever the eclipses of Jupiter's moons are visible.

The longitude shows on what meridian you are situated, and the latitude on what part of that meridian; therefore, when you can ascertain both these, you discover the very spot in which you are situated. But it is not only the secondary planets which produce eclipses, for the primary planets near the sun eclipse him to those at a greater distance, when they come in conjunction in the nodes of their orbits; but as the primary planets are much longer in performing their course round the sun, than the satellites in going round their primary planets, these eclipses very seldom occur.

Mercury and Venus have, however, passed in a right line between the earth and the sun, but being at so great a distance, their shadows did not extend so far as the earth. No darkness was therefore produced on any part

of our globe; but the planet appeared like a small black spot passing across the sun's disk: this is called a transit of the planet. It was by the last transit of Venus that astronomers were enabled to calculate, with some degree of accuracy, the distance of the earth from the sun, and the dimensions of the latter.

The tides are produced by the attraction of the moon. The cohesion of fluids being much less than that of solid bodies, they more easily yield to the power of gravity; in consequence of which the waters immediately below the moon are drawn up in a protuberance, producing a full tide, or what is commonly called high-water, at the spot where it happens. According to this theory it would be imagined that we should have the full tide only once in twenty-four hours—that is, every time that they were below the moon—while we find that we have two tides in the course of the twenty-four hours, and that it is high water with us and with our antipodes at the same time.

The influence of the sun on the tides is less than that of the moon; for observe, that the tides rise in consequence of the moon attracting one part of the waters more forcibly than another part: it is this inequality of attraction which produces full and ebb tides. Now the distance of the sun is so great, that the whole globe of the earth is comparatively but as a point, and the difference of attraction for that part of the waters most under its influence, and that part least subject to it, is but trifling; no part of the waters will be much elevated above, or much depressed below their general surface, by its action. The sun has, however, a considerable effect on the tides, and increases or diminishes them as it acts in conjunction with, or in opposition to, the moon.

The moon is a month in going round the earth; twice during that time, therefore, at full and at change, she is in the same direction as the sun. Both these act in conjunction, on the earth, and produce very great tides, called spring-tides; but when the moon is in the intermediate parts of her orbit, the sun, instead of affording assistance, weakens her power by acting in opposition to it; and smaller tides are produced, called neap-tides.

Since attraction is mutual between the moon and the earth, we produce tides in the moon; and these are more considerable in proportion as our planet is larger. Neither

the moon nor the earth in reality assumes an oval form, for the land which intersects the water destroys the regularity of the effect. The orbit of the moon being nearly parallel to that of the earth, she is never vertical but to the inhabitants of the torrid zone; in that climate, therefore, the tides are greatest, and they diminish as you recede from it, and approach the poles; but in no part of the globe is the moon immediately above the spot where it is high-tide. All matter, by its inertion, offers some resistance to a change of state; the waters, therefore, do not readily yield to the attraction of the moon, and the effect of her influence is not complete until some time after she has passed the meridian.

The earth revolves on its axis in about twenty-four hours: if the moon were stationary, therefore, the same part of the globe would every twenty-four hours return beneath the moon; but as during our daily revolution the moon advances in her orbit, the earth must make more than a complete rotation, in order to bring the same meridian opposite the moon: we are three-quarters of an hour in overtaking her. The tides, therefore, are retarded, for the same reason that the moon rises later, by three-quarters of an hour, every day. This, is only the average amount of the retardation. The time of the highest tide is modified by the sun's attraction, and is between those of the tides which would be produced by the separate action of the two luminaries. The action of the sun, therefore, makes the interval different on different days, but leaves the averagement unaffected.

MECHANICS.

ON THE LAWS OF MOTION, AND THE CENTRE OF GRAVITY.

THE science of Mechanics is founded on the laws of motion; it will therefore be necessary to explain these laws before we examine the mechanical powers. Motion consists in a change of place. A body is in motion whenever it is changing its situation with regard to a fixed point. Now, as one of the general properties of bodies is inertia, that is, an entire passiveness either with regard to motion or rest, it follows that a body cannot move without being put into motion: the power which puts a body into motion is called *force;* thus the stroke of the hammer is the force which drives the nail; the pulling of the horse that which draws the carriage. Gravitation is the force which occasions the fall of bodies; cohesion that which binds the particles of bodies together; and heat, a force which drives them asunder. The motion of a body acted upon by a single force is always in a straight line, in the direction of which it received the impulse.

The rate at which a body moves, or the length of time which it takes to move from one place to another, is called its velocity; and it is one of the laws of motion that the velocity of the moving body is proportional to the force by which it is put in motion. The velocity of a body is called *absolute,* if we consider the motion of the body in space, without any reference to that of other bodies. When, for instance, a horse goes fifty miles in ten hours, his velocity is five miles an hour. It is termed *relative,* when compared with that of another body which is still in motion. Thus a man sailing in a ship may remain at rest relatively to the vessel, though he partakes of its absolute motion; but if he walk the deck in the same direction as that in which the ship is sailing, his absolute motion will be increased by the rate at which he

moves along, and his relative motion will be the difference between his own absolute motion and that of the ship. So if two carriages go along the same road in the same direction, their relative velocity will be the difference of their absolute velocities; if in opposite directions, the same? If they start from the same point, along two roads, making an angle with each other, their relative motion will be measured by their distance, in a straight line, from each of the other after a given time, and the direction of this relative motion will be the direction of that line. The absolute velocity of a body is measured by the space over which it moves, in some particular time, selected as the standard; the velocity per hour, for instance, would be shown by dividing the number of miles travelled over by the number of hours occupied in the journey. Thus if you travel one hundred miles in twenty hours, and wish to know what is your velocity, you divide one hundred by twenty, and the answer will be five miles an hour. We say, also, that space is equal to the velocity multiplied by the time; if your velocity be three miles an hour, and you travel six hours, you will have gone in all a space of eighteen miles.

Uniform motion is that of a body which passes over equal spaces in equal times. It is produced by a force having acted on a body once and having ceased to act, such as the stroke of a bat on a cricket-ball. But it may be said, that the motion of a cricket-ball is not uniform, its velocity gradually diminishing till it falls to the ground. In answer to this objection, you must observe that the ball is inert, having no more power to stop than to put itself in motion; if it fall, therefore, it must be stopped by some force superior to that by which it was projected; and this force is gravity, which counteracts, and finally overcomes that of projection. If neither gravity nor any other force (such as the resistance of the air or friction of the ground) opposed its motion, the cricket-ball, or even a stone thrown by the hand, would proceed onwards in a right line and with a uniform velocity for ever! Yet we have no example of perpetual motion on the surface of the earth; because the causes referred to ultimately destroy all motion, whether produced by natural or artificial means.

When we study the celestial bodies, we find that

nature abounds with examples of perpetual motion, and that it conduces as much to the harmony of the system of the universe, as the prevalence of it would be to the destruction of all stability on the surface of the globe. Providence has therefore ordained insurmountable obstacles to perpetual motion here below; and though these obstacles often compel us to contend with great difficulties, yet the general result is, that order, regularity, and repose, so essential to the preservation of the various beings of which this world is composed.

Retarded motion is produced by some force acting on a body in a direction opposed to that which first put it in motion, and this gradually diminishes its velocity.

Accelerated motion is produced when the force which put a body in motion continues to act upon it during its motion so that its velocity is continually increased. Let us suppose, that the instant a stone is let fall from a high tower the force of gravity were annihilated: the stone would nevertheless descend, for a body having once received an impulse, will not stop (unless some obstacle impede its course), but move on with a uniform velocity. If, then, the force of gravity be not destroyed after having given the first impulse to the stone, but continues to act on it during the whole of its descent, it is easy to understand that its motion will be thereby accelerated. Let us suppose that the impulse given by gravity to the stone during the first instant of its descent be equal to one; the next instant we shall find that an additional impulse gives the stone an additional velocity equal to one; so that the accumulated velocity is now equal to two; the following instant another impulse increases the velocity to three, and so on till the stone reaches the ground. The spaces described in a given time follow a law slightly different; for it has been ascertained both by experiment and calculations, that heavy bodies descending from a height by the force of gravity, fall sixteen feet in the first second of time, three times that distance in the next, five times in the third second, seven times in the fourth, and so on, regularly increasing both their velocities and the spaces described according to the number of seconds during which the body has been falling. Thus the height of a building or the depth of a well may be

measured by observing the length of time which a stone takes in falling from the top to the bottom.

If a stone be thrown perpendicularly upwards, it is the same length of time ascending that it is descending. In the first case the velocity is diminished by the force of gravity; in descending it is accelerated by it. The force of projection given to a body in moving it upwards, is equal to the force with which it strikes the ground when it descends again, and this latter force is the effect produced by gravity during the time of its fall. If a stone be thrown upwards gently it will not rise high, and gravity will soon make it descend; if thrown with violence, it will rise higher, and gravity will be longer in bringing it back to the ground. Suppose that it be thrown with a force which will make it rise only sixteen feet, in that case it will fall in one second of time. Now it is proved by experiment, that an impulse requisite to project a body sixteen feet upwards, will make it ascend that height in one second; here then the times of the ascent and descent are equal. But suppose it be required to throw a stone twice that height, the force must be greater. Then the impulse of projection in throwing a body upwards, is equal to the accumulated effect produced by gravity during its descent; and it is the greater or less distance to which the body rises, that makes these balance each other, for it gives more time for the force of gravitation to act.

The *Momentum* of bodies is the force or power, with which a body in motion would strike against another body, so as to set the latter in motion. The momentum of a body is composed of its weight, multiplied by its velocity. The quicker a body moves, the greater will be the force with which it will strike against another body; so that a small light body may have a greater momentum than a heavy one, provided its velocity be sufficiently great. For instance, the momentum of an arrow shot from a bow is greater than that of a stone thrown by the hand. We know also by experience that the heavier a body is, the greater is its force; if it acts in other respects under the same circumstances, therefore, the whole power, or momentum of a body is composed of these two properties. But why should not these be added together, instead of being multiplied by one another? It is found by experi-

ment, that if the weight of a body be represented by the number 3, and its velocity also by 3, its momentum will be as 9; not 6, as would be the case were these figures added; instead of being multiplied together. The same conclusion may very easily be deduced by reasoning. If two bodies, one of one pound weight, the other of two, have the same velocity, the moving force of the second or its momentum, is double that of its first. If a third body also of two pounds, move with three times the velocity of the second, its momentum, the weights in this case being equal, is three times that of the second. But the momentum of the second is twice that of the first, therefore the momentum of the third is six times that of the first. By thus dividing the process, and looking first to the effect of a change of the velocity, and afterwards to that of the change of weight, it becomes evident that these effects are to be multiplied together.

The *Re-action* of bodies is the next law to be explained. When a body in motion strikes against another body it meets with resistance, the resistance of the body at rest will be equal to the blow struck by the body in motion; or, in philosophical language, action and re-action will be equal, and in opposite directions.

The most striking experiments on these subjects are made with elastic bodies. Elasticity is a property, by means of which bodies that are compressed return to their former state. If you bend a cane, as soon as it is at liberty it recovers its former position; if you press your finger on your arm, as soon as you remove it, the flesh, by virtue of its elasticity, rises and destroys the impression. Of all bodies, those in the form of air or gas are the most eminent for this property. Hard bodies are in the next degree elastic: if two ivory or metallic balls be struck together, the parts at which they touch will be flattened, but no mark is perceptible, their elasticity instantly destroying all trace of it. If, however, a very small spot of ink be placed on one of the balls at the point of contact, it will be found after the contact to have spread, and will thus show that there has been compression. Soft bodies, which easily retain impressions, such as clay, wax, tallow, butter, &c., have very little elasticity.

The cause of elasticity is not well ascertained. Elas-

ticity implies susceptibility of compression, and the susceptibility of compression depends upon the porosity of the bodies; for were there no pores or spaces between the particles of matter of which a body is composed, it could not be compressed. But we must not hence infer, that bodies whose particles are most distant from each other are most elastic. Elasticity implies not only susceptibility of compression, but the power of resuming its former state, after compression. The pores of such bodies as ivory and metals are invisible to the naked eye; but it is well ascertained that gold, one of the most dense of all bodies, is externally porous, and that its pores are sufficiently large to admit water, under great pressure, to pass through them. In cork, sponge, and bread, the pores form considerable cavities; in wood, and many kinds of stone, when not polished, they are perceptible to the naked eye; whilst in ivory, metals, and most varnished and polished bodies, they cannot be discovered. To give an idea of the extreme porosity of bodies, Sir Isaac Newton conjectured that if the earth was so compressed as to be absolutely without pores, its dimensions might possibly not be more than a cubic inch.

Birds, in flying, strike the air with their wings; and it is the re-action of the air which enables them to rise or advance forwards. The force with which their wings strike against the air must equal the weight of their bodies, in order that the re-action of the air may be able to support that weight; the bird will then remain stationary. If the stroke of the wings be greater than is required merely to support the bird, the re-action of the air will make it rise; if it be less, it will descend: the lark sometimes remains with its wings extended, but motionless; in this state it drops rapidity into its nest. A bird expands his wings when he gives the stroke, the re-action of which is to impel him onward, and contracts them when in the opposite direction. The swimming of fishes is on the same principle; their fins are expanded and contracted in a like manner; and a man in swimming strikes his hands out to produce the re-action which impels him forward, and turns them edgeways to lessen the effect of the contrary re-action. In rowing a boat, the oars are lifted out of the water after every stroke, so as completely to prevent any re-action in a backward direc-

tion; and even in moving them through the air they are turned edgeways, or feathered, as it is called, from its resemblance to the action of the feathers of a bird in flying.

Let us now return to the subject of re-action, on which we have some further observations to make. It is re-action being contrary to action which produces *reflected motion*. If you throw a ball against a wall it rebounds; this return of the ball is owing to the re-action of the wall against which it struck and is called reflected motion. A ball filled with air rebounds better than one stuffed with bran or wool, for the elasticity of the air re-acts after compression. If the ball be thrown perpendicularly against the wall it returns straight towards the hand, though the action of gravity draws it downwards before reaching it; but if thrown obliquely upwards it rebounds still higher. We use the term perpendicular in preference to the more familiar word straight, because straight is a general term for lines in all directions, which are neither curved nor bent, and is, therefore equally applicable to oblique or perpendicular lines. A perpendicular has always a reference to something towards which it is perpendicular; that is to say, that it inclines neither to the one side nor the other, but makes an equal angle on either side.

We shall now proceed to circular motion; this is the result of the action of two forces on a body, by one of which it is projected forward in a right line, whilst by the other it is continually directed towards a fixed point. For instance, if I whirl a ball fastened to my hand with a string, the ball will have a circular motion, because it is acted on by two forces, that I give it, which represents the force of projection, and that of the string, which confines it to my hand. If during its motion I were suddenly to cut the string, the ball would fly off in a straight line; being released from confinement to the fixed point, it would be acted on but by one force, and motion produced by one force is always in a right line. When a mop is trundled the threads fly from the centre; but being confined to it at one end they cannot part from it; whilst the water they contain is thrown off in straight lines. In the same way, the flyers of a windmill, when put in motion by the wind, would be driven straight

forward in a right line, were they not confined to a fixed point, round which they are compelled to move. The point to which the motion of a small body, such as the ball with the string, is confined, becomes the centre of its motion, for it may be considered as moving in the same plane or flat surface. But when a body is not of a size or shape to allow of our considering every part of it as moving in the same plane, it revolves round a line, which is called the axis of motion. In a top, for instance, when spinning on its point, the axis is the line which passes through the middle of it, perpendicularly to the floor. The axle of the sails of a windmill is the axis of its motion. The centre of motion is not always in the middle of a body.

The middle point of a body is called its centre of magnitude, that is, the centre of its mass or bulk. Bodies have also another centre, called the centre of gravity, which shall be explained; but at present, we must confine ourselves for a short time longer to the axis of motion. This line remains at rest, while all the other parts of the body move around it; when a top is spun, the axis is stationary, whilst every other part is in motion round it. A top, it is true, has also generally a motion forwards, besides its spinning motion; and then no point within it can be at rest. But what is said of the axis of motion relates only to circular motion; that is to motion round a line, and not to that which a body may have at the same time in any other direction.

There is one circumstance in circular motion, which must be carefully attended to; it is, that the further any part of a body is from the axis of motion, the greater is its velocity: as you approach that line, the velocity of the parts gradually diminishes till you reach the axis of motion which is perfectly at rest. The extremities of the flyers of a windmill move over a much greater space than the parts nearest the axis of motion.

The force which confines a body to a centre, round which it moves, is called the *centripetal* force; and the power which impels a body to fly from the centre is called the *centrifugal* force; in circular motion these two forces balance each other; otherwise the revolving body would either approach the centre or recede from it, according as the one or the other prevailed. And should

any cause destroy the centripetal force, the centrifugal force would impel the body to fly off from the centre. It would not, however, fly off in a right line from the centre, but in a right line in the direction it was moving at the instant of its release: if a stone whirled round in a sling, gets loose, it flies off at a tangent. This force would, therefore, with more propriety, be called the tangential than the centrifugal force, or rather, inertia of the body which inclines it to move in the direction of the tangent is the tangential force. But motion in the direction of the tangent would remove the body further from the centre, and that part of its force which tends to produce motion thus away from the centre is called the centrifugal force.

If a ball be thrown in a horizontal direction, it is acted on by no less than three forces: the force of projection first given to it; the resistance of the air through which it passes; and the force of gravity which finally brings it to the ground. Gravity and the resistance of the air act continually; and as the whole effect produced by them is always so great as to overpower any force of projection we can communicate to a body, the latter is gradually overcome, and the body brought to the ground; but the stronger the projectile force, the longer will these powers be in subduing it. A shot fired from a cannon, for instance, will go much further than a ball thrown by the hand. Bodies thus projected described a curved line in their descent. If the forces of projection and of gravity both produced uniform motion, the ball would move in the diagonal of a parallelogram, but the motion produced by the force of projection by gravity is accelerated; and it is this acceleration which brings the ball sooner to the ground, and makes it fall in a curve instead of a straight line.

We have not taken notice of the resistance of the air, which much complicates these results in practice. The principles of its operation may easily be understood from the mode in which the other forces act; but the degree and manner in which it modifies their effects cannot be shown without much difficulty and intricacy of explanation. It is, however, sufficiently plain that this resistance increases with the velocity of the ball, for the particles of

air react on the ball in proportion to the stroke they receive from it; so that if the force of projection be doubled, the resistance of the air is doubled also, nor is this all, for in doubling the velocity of the ball, it passes through twice the quantity of air in the same time, and receives twice the resistance from each particle; the whole of the resistance must therefore be four times as great as in the first instance. And if the velocity of the ball be tripled, it will pass through three times the quantity of air; will strike each particle with three times the force, and receive three times the re-action; which summed up will make nine times the resistance.

The shortest mode of calculating the resistance is to multiply the velocity by itself; thus, if the velocity be three, multiply it by three and the product will be nine. The product of a number multiplied by itself is called its square.

The curve line which a ball describes, if the resistance of the air be not taken into consideration, is called in geometry a *parabola*. But when the ball is thrown perpendicularly upwards, it will descend perpendicularly; because the force of projection, and that of gravity, are in the same line of direction.

We noticed the centres of magnitude and of motion, but we have not as yet explained what is meant by the centre of gravity. It is that point about which all the parts of a body exactly balance each other, in every position of the body; if therefore, that point is supported, the body will not fall. Were any other point of the body alone supported, the surrounding parts no longer balancing each other, the body would fall on the side at which the parts are heaviest; therefore, whenever the centre of gravity is unsupported the body must fall. This sometimes happens with an over-loaded waggon winding up a steep hill, one side of the road being higher than the other. It is dangerous, when a boat is in any risk of being upset, for the passengers to rise suddenly; this is owing to their raising the centre of gravity, and thus increasing the chance of throwing it out of the line of direction. When a man stands upright, the centre of gravity is supported by his feet. If he lean on one side he will no longer stand firm. A rope-dancer performs all his feats of agility, by dex-

terously supporting his centre of gravity; whenever he finds himself in danger of losing his balance, he shifts the heavy pole, which he holds in his hands, in order to throw the weight towards the side that is deficient; and thus by changing the situation of the centre of gravity, restores his equilibrium.

A stick is balanced on the point of the finger, by supporting its centre of gravity; and it is for want of this support that spherical bodies roll down a slope. A sphere being perfectly round can touch the slope but by a single point, and that point is not perpendicularly under the centre of gravity, which therefore is not supported. The centre of gravity, in this case, coincides with the centre of magnitude, but when one part of the body is composed of heavier materials than another part, the centre of gravity, being the centre of the weight of the body, will generally no longer correspond with the centre of magnitude, though it may accidently do so.

Bodies having a narrow base are easily upset, for if they are the least inclined, their centre is no longer supported. A person carries a single pail of water with great difficulty, owing to the centre of gravity being thrown on one side, and the opposite arm is stretched out to endeavour to bring it back to its original situation. But two pails, one hanging on each arm, are carried with much greater facility, because they balance each other.

When two bodies are fastened together by a rod, they are to be considered as forming but one body. If the two bodies be of equal weight the centre of gravity will be in the centre of the line which unites them, but if one be heavier than the other, the centre of gravity will be proportionably nearer the heavy body than the light one.

ON THE MECHANICAL POWERS.

The mechanical powers are six in number, one or more of which enters into the composition of every machine. The *lever*, the *pulley*, the *wheel* and *axle*, the *inclined plane*, the *wedge*, and *screw*.

In order that we may understand the power of a machine there are four things which claim our consideration.

1st. The power that acts: this consists in the effect of men or horses, of weights, springs, steam, &c.

2ndly. The resistance which is to be overcome by the power; this is generally a weight to be moved. The effect of the power acting in the manner which in each particular case it is applied, must always be superior to the resistance, otherwise the machine could not be put in motion. For instance, were the resistance of a carriage equal to the strength of the horses employed to draw it, they would not be able to make it move.

3rdly. We are to consider the centre of motion, or as it is termed in mechanics, the fulcrum, which means a prop; this is the point about which all parts of the body move: and,

Lastly, The respective velocities of the power, and of the resistance.

We shall first examine the power of the lever. The lever is an inflexible rod or beam, that is to say, one which will not bend in any direction. For instance, the steel rod to which a pair of scales is suspended is a lever, and the point by which it is suspended, called the prop or fulcrum, is also the centre of motion. The two parts of a lever, divided by a fulcrum, are called its arm. Now, both scales being empty, they are of the same weight, and consequently balance each other. We have previously stated, that when two bodies of equal weight were fastened together, the centre of gravity would be in the middle of the line that connected them; the centre of gravity of the scales must, therefore, be in the middle between them, as the fulcrum is, and this being supported, the scales balance each other.

We must bear in mind, that if a body be suspended by that point in which the centre of gravity is situated, it will remain at rest in any position indifferently; which is not the case with this pair of scales, for when we hold them inclined, they instantly regain their equilibrium; the reason of this is, that the centre of suspension, instead of exactly coinciding with that of gravity, is a little above it; if therefore, the equilibrium of the scales be disturbed; the centre of gravity moves in a small circle round the point of suspension, and is therefore forced to rise, and the instant it is restored to liberty it descends and resumes its situation immediately below the point of suspension, when the equilibrium is restored. It is this property which renders the balance so accurate an instrument for weighing goods. If the scales contain different weights the centre of gravity will be removed towards the scale which is heaviest, and being no longer supported, the heaviest scale will descend. The fulcrum of the balance is moveable; the lever may be taken off the prop and fastened on in another point which then becomes the fulcrum. In this case the equilibrium is destroyed, the longest arm of the lever is heaviest and descends. The centre of gravity is not supported because it is no longer immediately below the point of suspension; but if we can bring the centre of gravity immediately below the point, as it is now situated, the scales will again balance each other. Now if a heavy weight be placed in the scale suspended to the shortest arm of the lever, and a lighter one into that suspended to the longest arm, the equilibrium will be restored. It is not therefore, impracticable to make a heavy body balance a light one; and by this means, an imposition in the weight of goods is very frequently effected by dishonest dealers, as a weight of ten or twelve ounces might thus be made to balance a pound of goods. An ingenious balance, called a steelyard, has been invented on the principle that a weight increases in effect, in proportion to its distance from the fulcrum. In this machine, for instance, a single pound weight answers the purpose of weighing any quantity of goods, simply by moving it along the lever; for in proportion as it recedes from the fulcrum, it will balance five, ten, twenty, fifty, or perhaps even as many as a hundred pounds weight. The

hook by which the instrument is suspended, forms the fulcrum; it is, for instance two inches distant from the basin which is to contain the articles to be weighed, while the opposite arm of the lever extends two feet; a small weight is suspended to it, and the graduations on the lever indicate the different powers of this weight according to the situation which it occupies on the long arm of the lever; when pushed to the extremity a weight of five pounds is equivalent to sixty pounds placed in the basin. The same steelyard when suspended by a second hook, which divides the lever with less inequality, and corresponds with another scale of graduation, is used for weighing smaller quantities of goods, and the same weight when hung at the extremity may be equal to twenty pounds placed in the basin.

Let us now return to the balance, and divesting it of the basins, consider the lever simply. In this state the fulcrum is no longer in the line of direction of the centre of gravity, but it is, and must ever be, the centre of motion, as it is the only point which remains at rest while the other parts move about it. When a lever is put in motion, the longest arm or acting part of the lever must move with greater velocity than the shortest arm, or resisting part of the lever, because it is farthest from the centre of motion. When two boys ride on a plank drawn over a log of wood, the plank becomes a lever, the log which supports it the fulcrum, and the two boys the power and the resistance at each end of the lever. When the boys are of equal weight, the plank must be supported in the middle to make the two arms equal;—if they differ in weight, the plank must be drawn over the prop so as to make the arms unequal, and the lightest boy be placed at the extremity of the longest arm, in order that the greater velocity of his motion may compensate for the superior gravity of his companion, so as to render their momentions equal. But we know that the action of the power must be greater than the resistance, in order to put the machine in motion. For this purpose, each boy at his descent touches the ground with his feet, and the support he receives from it diminishes his weight and enables his companion to raise him; thus each boy alternately represents the power and the weight, and the two arms alternately

perform the junction of the acting and the resisting part of the lever.

A lever, in moving, describes the arc of a circle, for it can move only around the fulcrum or centre of motion. It would be impossibe for one child to rise perpendicularly, or for the other to descend in a straight line; they describe arcs of their respective circles; and you may judge from the different dimensions of the circle how much greater the velocity of the little child must be than that of the bigger one. Enormous weights may be raised by levers of this description, for the longer the acting part of the lever in comparison to the resisting part, the greater is the effect produced by it; because the greater is the velocity of the power compared to that of the weight. You may have seen a heavy snow-ball rolled over by thrusting the end of a long stick beneath the ball, and resting it against a log of wood, or any other object which may give it support, near the end in contact with the snow-ball. The stick in this case is a lever; the support, the prop or fulcrum; and the nearer the latter is to the resistance, the more easily will the power be able to move it.

There are three different kinds of levers—in the first, which comprehends the several levers we have been describing, the fulcrum is between the power and the weight. When the fulcrum is situated equally between the power and the weight as in the balance, the power must be greater than the weight, in order to move it; for nothing can in this case be gained by velocity. The two arms of the lever being equal, the velocity of their extremities must be so likewise. The balance is, therefore, of no assistance as a mechanical power, but it is extremely useful to estimate the respective weights of bodies. But when the fulcrum of a lever is not equally distant from the power and the weight, and that in amount, though greater in effect, the power acts at the extremity of the longest arm, it may be less than the weight, its deficiency being compensated by its superior velocity; as we observed in the case of the boys and the *see-saw*. Therefore, when a great weight is to be raised, it must be fastened to the shortest arm of the lever, and the power applied to the longest arm; but if the case will admit of putting the end of the lever under the

weight, no fastening will be required, as you may perceive by stirring the fire. The poker is a lever of the first kind; the point where it rests against the bars of the grate, whilst stirring the fire, is the fulcrum; the short arm, or resisting part of the lever is employed in lifting the weight, which is the coals, and the hand is the power applied to the longest arm, or acting part of the lever. A pair of scissors is an instrument composed of two levers united in one common fulcrum; the point at which the two levers are screwed together is the fulcrum; the handles to which, to which the power of the fingers are applied, are the extremities of the acting part of the levers, and the cutting part of the scissors are the resisting parts of the levers; therefore, the longer the handles, and the shorter the points of the scissors, the more easily will they cut. Thus, when pasteboard, or any hard substance is to be cut, that part of the scissors nearest the screw, or rivet, is used. Snuffers, and most kinds of pincers, are levers of a similar description, the great force of which consists in the resisting part of the lever being very short in comparison of the acting part.

In levers of the second kind, the weight, instead of being at one end, is situated between the power and the fulcrum. In moving it, the velocity of the power must necessarily be greater than that of the weight, as it is more distant than the centre of motion. Let us take, for example, a snow-ball moved by means of a lever of the second order, as well as by one of the first. The end of the stick that is thrust under the ball rests on the ground, which becomes the fulcrum; the ball is the weight to be moved, and the power the hands applied to the other end of the lever. In this instance, there is an immense difference in the length of the arms of the lever, the weight being almost close to the fulcrum, and the advantage gained is proportional. Fishermen's boats are thus raised from the ground to be launched into the sea, by means of slippery pieces of board, which are thrust under the keel. The most common example that we have of levers of the second kind is in the doors of our apartments: in these the hinges represent the fulcrum, the hand, the power applied to the other end of the lever, and the door, or rather its inertia, is the weight which occupies the whole of the space between the power and the fulcrum.

The whole weight and inertiea of the door may be regarded as collected into its centre of gravity; that is to say, the resistance of the door is the same that would be offered by a force equal to the inertia of the door, and passing through its centre of gravity. Another very common instance is found in an oar: the blade is kept in the same place by the resistance of the water, and becomes the fulcrum; the resistance is applied where the oar passes over the gunwale of the boat, and the hands at the handle are the power. Nut-crackers are double levers of this kind: the hinge is the fulcrum. the nut the resistance, and the hands the power.

In levers of the third kind the fulcrum is also at one of the extremities, the weight or resistance at the other, and it is now the power that is applied between the fulcrum and the resistance. Thus the fulcrum, the weight, and the power, each in its turn occupies some part of the lever between its extremity. But in this third kind of lever, the weight being farther from the centre of motion than the power, the difficulty of raising it instead of being diminished is increased. Levers of this description are used when the object is to produce great velocity. The aim of mechanics in general, is to gain force, by exchanging it for time; but it is sometimes desirable to produce great velocity by an expenditure of force. The treddle of a common turning lathe affords an example of a lever of the third kind employed in gaining time, or velocity, at the expense of force. A man in raising a long ladder perdendicularly against a wall, cannot place his hands on the upper part of the ladder; the power, therefore, is necessarily placed nearer the fulcrum than the weight, for the hands are the power, the ground the fulcrum, and the ladder the weight; which, as in the case of a door, may be considered as collected in the centre of gravity of the ladder, about half way up, and consequently beyond the point where the hands are applied. Nature employs this kind of lever in the structure of the human frame. In lifting a weight with the hand, the lower part of the arm becomes a lever of the third kind; the elbow is the fulcrum; the muscles which move the arm, the powers; and as these are nearer to the elbow than the hand is, it is necessary that their power should exceed the weight to be raised.

It may perhaps be matter of wonder that nature should have furnished us with such levers, but the disadvantage is more than compensated by the convenience resulting from the structure of the arm. It is of more consequence that we should be able to move our limbs nimbly, than that we should be able to overcome great resistance, for it is comparatively seldom that we meet with great obstacles, and when we do, they can be overcome by art. Besides, the Creator has endowed the muscular fibres with prodigious strength, so that upon the whole this kind of lever is best adapted to enable the arm to perform its various functions.

We will now direct our attention to the *Pulley*, which is the second mechanical power. It is a circular flat piece of wood or metal, with a string running in a groove round it, by means of which a weight may be pulled up. Thus pulleys are used for drawing up curtains, the sails of a ship, &c. When the pulley is fixed it does not increase the power to raise the weight. It is evident therefore, that the power must be greater than the weight to move it. A fixed pulley is useful, therefore, only in altering the direction of the power, and its most frequent application is to make us draw up a weight by drawing down the string connected with the pulley. But a moveable pulley affords mechanical assistance. The hand which sustains a cask by means of the cord going over the moveable pulley, does it more easily than if it held the cask suspended to a cord without a pulley; for the fixed hook., to which one end of the cord is fastened, bearing one half of the weight of the cask, the hand has only the other half to sustain. Now it is evident, that the hook affords the same assistance in raising as in sustaining the cask, so that the hand will only have one half the weight to raise. But observe, that the velocity of the hand must be double to that of the cask; for in order to raise the latter one inch, the hand must draw the two strings one inch each; the whole string being shortened two inches, while the cask is raised only one. Thus the advantage of a moveable pulley consists in dividing the difficulty; twice the length of string it is true must be drawn, but only half the strength is required which would be necessary to raise the weight without such assistance: so that the difficulty is overcome in the same manner as it

would be by dividing the weight into two equal parts, and raising them successively. It may perhaps be objected to pulleys that a longer time is required to raise a weight with their aid than without it; that is true, for it is a fundamental law in mechanics, that what is gained in power is lost in time: this applies not only to the pulley, but to the lever, and all the other mechanical powers. It would be wrong however, to suppose that the loss was equivalent to the gain, and that we derived no advantage from the mechanical powers; for since it is entirely beyond our power to augment our bodily strength, it must be admitted that science is of the greatest utility that enables us to reduce the resistance or weight of any body to the level of our strength. This we accomplish by dividing the resistance of a body into parts which we can successively overcome; and if it require a sacrifice of time to attain this end, we must be very sensible how very advantageously it is exchanged for power. The greater the number of pulleys connected by a string, the more easily the weight is raised, as the difficulty is divided amongst the number of strings, or rather of parts into which the string is divided by the pulleys. Several pulleys thus connected form what is called a system or tackle of pulleys. They may be seen suspended from cranes to raise goods into warehouses, and in ships to draw up the sails. Here both the advantages of an increase of power and a change of direction are united; for the sails are raised up the masts by the sailors on deck from the change of direction which the pulley effects; and the labour is facilitated by the mechanical power of a combination of pulleys. Pulleys are frequently connected, both for nautical and other purposes; but in whatever manner pulleys are connected by a single string, the mechanical power is the same in its principle. The wheel and axle is the third mechanical power. Let us suppose the weight to be a bucket of water in a well, which is to be raised by winding the rope, to which it is attached, round the axle; if this be done without a wheel to turn the axle, no mechanical assistance is received. The axle without a wheel is as impotent as a single fixed pulley, or a lever, whose fulcrum is in the centre; but add the wheel to the axle, and you will immediately find the bucket is raised with much less difficulty. The axle acts the part of the shorter arm of the lever, the wheel that

of the longer arm. The velocity of the circumference of the wheel is as much greater than that of the axle, as it is further from the centre of motion; for the wheel describes a large circle in the same space of time that the axle describes a small one, therefore the power is increased in the same proportion as the circumference of the wheel is greater than that of the axle. If the velocity of the wheel were twelve times greater than that of the axle, a power nearly twelve times less than the weight of the bucket would be able to raise it. Instead of a wheel there is more commonly attached to the axle a crooked handle, which answers the same purpose. For the branch of the handle which is united to the axle represents the spoke of a wheel, and is as effectual as an entire one; the other branch affords no mechanical aid, merely serving as a handle to turn the wheel. Wheels are a very essential part of machines. They are employed in various ways; but, when fixed to the axle, their mechanical power is always the same; that is, as the circumference of the wheel exceeds that of the axle, so much will the energy of the power be increased. In mills and manufactories, no person has seen without admiring the immense wheel, the revolution of which puts the whole of the machinery into motion; and though so great an effect is produced by it, a horse or two has sufficient power to turn it; but the steam engine is both the most powerful and the most convenient mode of turning the wheel. We have the advantage sometimes of a gratuitous force, such as a stream of water to turn the wheel of a water-mill; and the wind which acts upon the sails of a windmill. One of the great benefits resulting from the use of machinery is, that it gives us, as it were, a sort of empire over the powers of nature, and enables us to make them perform that labour which would otherwise fall to the lot of man. When a current of wind, a stream of water or the expansive force of steam performs our task, we have only to superintend and regulate their operations.

The fourth mechanic power is the *Inclined Plane*. This is nothing more than a gentle slope or declivity, frequently used to facilitate the drawing up of weights. It is not difficult to understand, that a weight may with much greater ease be drawn up a slope than it can be raised the same height perpendicularly. But in this as well as the

other mechanical powers, the facility is purchased by a loss of time.

The *Wedges*, which is the next mechanical power, is composed of two inclined planes; it is frequently used by woodcutters to cleave wood. The resistance consists in the cohesive attraction of the wood, or any other body which the wedge is employed to separate; and the advantage gained by this power is in the proportion of half its width to its length. The wedge, however, acts principally by being struck, and not by mere pressure: the proportion stated is that which expresses its power when acting by pressure only.

All cutting instruments are constructed upon the principle of the inclined plane, or the wedge. Those that have but one edge sloped, like the chisel, may be referred to the inclined plane; whilst the axe, the hatchet, and the knife (when used to chop or split asunder), act on the principle of the wedge. But a knife cuts best when drawn across the substance it is to divide, as it is used in cutting meat, for the edge of a knife is really a very fine saw, and therefore acts best when used like that instrument.

The *Screw* which is the last mechanical power, is much more complicated than the others. It is composed of two parts, the screw and the nut. The screw is a cylinder, with a spiral protuberance coiled round it, called the thread, the nut is perforated to contain the screw; and the inside of the nut has a spiral groove, made to fit the spiral thread of the screw; just like the lid of a box which screws on. The handle which projects from the nut is a lever, without which the screw is never used as a mechanical power. The nut, with a lever attached to it is commonly called a winch. The power of the screw complicated as it appears, is referable to one of the most simple of the mechanical powers, the inclined plane. If a slip of paper be cut in the form of an inclined plane, and wound round a pencil, which will represent the cylinder, it will describe a spiral line corresponding to the spiral protuberance of the screw. The nut then ascends an inclined plane, but ascends it in a spiral instead of a straight line. The closer the thread of the screw the more easy is the ascent, but the greater are the number of revolutions the winch must make; so that we return to the old prin-

ciple—what is saved in power is lost in time. The power of the screw may be increased also, by lengthening the lever attached to the nut; it is employed either for compression or to raise heavy weights. It is used in cider and wine presses, in coining, book binding, and for a variety of other purposes.

All machines are composed of one or more of the six mechanical powers we have been examining and explaining. One more remark must be made relative to them, which is, that friction in a considerable degree diminishes their force. Friction is the resistance which bodies meet with in rubbing against each other. There is no such thing as perfect smoothness or evenness in nature. Polished metals, though they wear that appearance, more than any other bodies, are really far from possessing it; and their inequalities may frequently be perceived through a good magnifying glass. When therefore the surfaces of the two bodies come into contact, the prominent parts of the one will often fall into the hollow parts of the other, and occasion more or less resistance to motion. In proportion as the surfaces of bodies are well polished, the friction is diminished; but it is always considerable and it is usually computed to destroy one-third of the power of a machine. Oil or grease is used to lessen friction; it acts as a polish by filling up the cavities of the rubbing surfaces, and thus making them slide more easily over each other. It is for this reason that wheels are greased, and the locks and hinges of doors oiled. In these instances, the contact of the rubbing surfaces is so close, and the rubbing so continual, that, notwithstanding their being polished and oiled, a considerable degree of friction is produced. It is a remarkable circumstance, that there is generally less friction between two bodies of different substances, than of the same. It is on this account that the holes in which the spindles of watch works are frequently made of jewels; and that when two cog-wheels work in one another, the cogs of the one are generally made of wood and of the other of metal.

There are two kinds of friction; the one occasioned by the sliding of the flat surface of a body, the other by the rolling of a circular body. The friction resulting from the first is much the most considerable, for great force is required to enable the sliding body to overcome the re-

sistance which the asperities of the surfaces in contact oppose to its motion, and it must be either lifted over, or break through them; whilst, in the other kind, the friction is transferred to a small surface, and the rough parts roll over each other with comparative facility; hence it is, that wheels are often used for the sole purpose of diminishing the resistance of friction. Where, in descending a steep hill, we fasten one of the wheels, we decrease the velocity of the carriage by increasing the friction, that is to say, by converting the rolling friction of one of the wheels into the dragging friction; and when castors are put to the legs of a table the dragging is converted into the rolling friction.

The great fly-wheel which is frequently attached to steam engines and other large machines, acts in the first instance as a heavy weight to impel their free uncontrolled motion. However paradoxical this mode of improving machinery may appear to be, it is nevertheless of great advantage. The motion of a machine is always more or less variable, owing to the irregularity, both of the power which works it, and of the resistance which it has to overcome. Whether the power consists in wind, water, steam, or the strength of animals, it cannot be made to act with perfect regularity, nor can the work which the machine has to perform be always uniform. Yet in manufactures, and most cases in which machinery is employed, uniformity of action is essentially requisite, both in order to prevent injury to the machine, and imperfection in the work performed. A fly-wheel, which is a large heavy wheel attached to the axis of one of the principal wheels of the machinery, answers this purpose by regulating the action of the machine: by its weight it diminishes the effect of increased action, and by its inertia it carries on the machine with uniform velocity, when the power transiently slackens; thus by either checking or impelling the action of the machine, it regulates its motion so as to render it tolerably uniform.

There is another circumstance which we have already noticed as diminishing the motion of bodies, and which greatly affects the power of machines: this is the resistance of the medium in which a machine is worked. All fluids, whether of the nature of air, or of water, are called mediums; and their resistance is generally propor-

tioned to their density: for the more matter a body contains, the greater the resistance it will oppose to the motion of another body striking against it. It is, therefore, more difficult to work a machine under water than in the air. If a machine could be worked in *vacuo*, and without friction, it would be perfect; but this is unattainable. A considerable reduction of power must, therefore, be allowed for the resistance of the air.

While on this subject, we may be allowed to make a few observations on tools. The difference between a *tool* and a *machine* is not capable of very precise distinction; nor is it necessary, in a popular explanation of those terms, to limit very strictly their acceptation. Various operations occur in the arts, in which the assistance of an additional hand would be a great convenience to the workman, and in these cases tools of the simplest construction come to his ready aid. The simpler machines are often only one or more tools placed in a frame, and acted on by any moving power. In pointing out the advantages of tools, we shall give an example of one of the simplest.

To arrange twenty thousand needles thrown promiscuously into a box, mixed and entangled with each other in every possible direction, in such a form that they shall be all parallel one with another, would at first sight appear a most tedious and difficult operation; in fact, if each needle were to be separated individually, many hours must be occupied in the process. Yet this is an operation which must be performed many times in the manufacture of needles; and it is accomplished in an incredible short space of time—a few minutes, by a very simple tool; nothing more being requisite than a small flat tray of sheet iron, slightly concave at the bottom. The needles are placed in it, and shaken in a peculiar manner, by throwing them up a very little, and giving at the same time a slight longitudinal motion to the tray. The shape of the needles assist their arrangement; for if two needles cross each other, (unless, which is exceedingly improbable, they happen to be precisely balanced,) they will, when they fall on the bottom of the tray, tend to place themselves side by side, and the hollow form of the tray assists this disposition. As they have no projection on any part to impede this tendency, or to entangle

each other, they are, by continually shaking, arranged lengthwise in three or four minutes. The direction of the shake is now changed; the needles are but little thrown up, but the tray is shaken edgways; the result of which is, that in a minute or two, the needles which were previously arranged endways, become heaped up in a wall, with their ends against the extremity of the tray. They are now removed by hundreds at a time, by raising them with a broad iron spatula, on which they are retained by the forefinger of the left hand. During the progress of the needles towards their finished state, this parallel arrangement must be repeated several times; and, unless some such cheap and expeditious method had been devised, the expense of manufacturing needles would have been considerably enhanced.

Another process in the art of making needles furnishes an example of one of the simplest contrivances which can come under the denomination of a *tool*, the efficiency of which for the purpose required no one will deny. After the needles have been arranged in the manner we have been describing, it is necessary to separate them into two parcels, in order that their points may all be placed in one direction. This is for the most part done by women and children. The needles are placed sideways in a heap, on a table or bench, in front of each operator, just as they are arranged by the process above described. From five to ten are rolled towards this person by the forefinger of the left hand; this separates them a very small space from each other, and each in its turn, is pushed lengthwise to the right or to the left, according as its eye is on the right or the left hand. This is the usual process, and in it every needle passes individually under the finger of the operator. A small alteration expedites the process considerably; the child puts on the forefinger of its right hand a small cloth cap, or finger-stall, and rolling out of the heap from six to twelve needles, he keeps them down by the forefinger of the left hand whilst he presses the forefinger of the right hand gently against their ends: those which have the points towards the right-hand stick into the finger-stall; and the child removing the finger of the left hand, slightly raises the needles sticking into the cloth, and then pushes

them towards the left side. Those needles which had their eyes on the right hand do not stick into the finger cover, and are pushed away to the heap on the right side previously to the repetition of this process. By means of this simple and ingenious contrivance, each movement of the finger from one side to the other, carries five or six needles to their proper heap; whereas, in the former method, frequently only one was moved, and rarely more than two or three were transported at one movement to their place.

PNEUMATICS.

THE science of Pneumatics treats of the density, pressure, and elasticity of the air, and the effects which they produce.

The air is the fluid in which we live and breathe; it entirely envelopes the globe, and extends to an unknown height above its surface. It is, together with the clouds and vapours that float in it, called the *atmosphere*.

Anciently, the air was supposed to be destitute of weight, and Galileo was the first who proved, by experiments, the fallacy of this supposition; and it is now sufficiently manifest, that like all other fluids, it presses upon bodies in proportion to the depths they are immersed in it; and that the pressure is in every direction, or on all sides of such bodies. It differs from most other fluids in the four following particulars: 1. It can be compressed into a much less space than it naturally possesses. 2. It cannot be congealed or reduced to a solid state. 3. It is of a different density in every part upwards from the earth's surface, decreasing in its weight as its distance from the earth increases. 4. Its elasticity, or the force with which it springs, is equal to the incumbent weight.

The air being perfectly invisible, and affording no resistance to the touch, it is not surprising that, according to vulgar apprehension, it should not be considered as a solid substance, and yet that it possesses weight, and great power of resistance to other bodies, many simple experiments may be devised to prove. A bladder, open at the aperture of the neck, may have its sides pressed together with the greatest ease; but if a bladder is filled by blowing air into it, and a string tied fast round its neck, it becomes impossible to press the sides together without bursting, and a very slight alteration of its figure requires considerable pressure. This resistance evidently proves that air is matter.

It is the great transparency of the air, which, in the

common acceptation of the term, renders it invisible; but the blue colour of the sky may be considered as the colour of the air, for this blueness is occasioned by the light reflected from the air, and the particles it contains. If, however, the atmosphere was absolutely transparent, it would reflect no light; every object would then be in total darkness, except it received the direct rays of the sun, and the stars would be visible at noonday.

The pressure of the atmosphere is removed for philosophical purposes by means of the air-pump. With this machine, a great variety of interesting experiments may be performed in proof of the properties of the atmosphere; without it, indeed, pneumatics would scarcely deserve the name of a science.

When the gravity of the air had once become known, it may be thought that it could not have been very difficult to account for some of its more remarkable effects, such as the ascent of water in the body of a pump. The contrary, however, appears to have been the case. Some Italian artists having received orders to construct a common pump for the purpose of raising water to the height of 50 or 60 feet, found, to their astonishment, that about 33 feet was the limit to which the water would rise. Galileo was applied to for an examination of this circumstance; and as he had accepted the current opinion, that the only reason why water rose at all in pumps was nature's abhorrence of a vacuum, so to this inquiry he answered, that nature did not entertain the horror of a vacuum beyond 33 feet! Galileo had afterwards reason to suppose that he had not given a very philosophical answer to the question put to him, but Torricelli, a pupil of his, was the first who conjectured that water is elevated in pumps by the pressure of the exterior air; and that the amount of this pressure could counterbalance no more than a column of water 33 feet high. He instituted an experiment that at once verified his conjecture, and proved the origin of that important invention, the barometer. He took a glass tube of about three feet in length, hermetically sealed at one end, and open at the other; he filled it with pure mercury, and stopping the orifice with his finger, he reversed the tube, and placed the open end in a vessel full of the same mercury. He had no sooner removed his finger than the

column of mercury, which was about 36 inches long, was reduced to the length of about 28 inches. This height being to that of 33 feet, in the inverse ratio of the densities of water and mercury, he concluded that, as he had conjectured, it was the pressure of the air which caused both water and mercury to rise until an equilibrium was produced. The experiment thus tried is called the Torricellian experiment, and the space left at the top of the tube, the Torricellian vacuum. It is the nearest approach to a perfect vacuum which the art of man can form, and is much superior to that of the best air-pump.

The pressure of the atmosphere is not always the same at the same place. These changes take place chiefly in countries at a distance from the equator. In Great Britain the barometer has been known to vary more than an inch in a few hours. Supposing the surface of a middle sized man, equal to fourteen and a half feet square, the pressure upon him, when the atmosphere is lightest is equal to thirteen and a half, and when heaviest, it is about fourteen and one third tons. The immense pressure we sustain does not impede our motions, because the pressure on one side is balanced by an equal pressure on the opposite side, nor is it capable of crushing the human frame, because the elastic force of the air, or some other elastic fluid within the body, is just sufficient to resist every injurious effect. So far from the pressure of the atmosphere being a disadvantage it is indispensable; and we find that our frame is braced, and that we are never more alert and active than in clear and fine weather when the mercury stands highest, and consequently the pressure of the atmosphere is greatest; on the contrary, when the mercury falls and the weight of the air diminishes, we feel listless and uncomfortable.

PNEUMATICAL INSTRUMENTS.

Ever since it was observed that the height of a column of mercury, sustained in a tube by the pressure of the atmosphere, varied in height at different times, and that these variations were accompanied or followed by changes in the weather, such an instrument has been applied to meteorological purposes, under the name of the *barometer.*

The *Thermometer* is a chemical rather than a pneumatical instrument, but it claims notice as a useful appendage to the barometer. All substances expanding with an increase of their temperature, it is obvious that, under the same pressure of the atmosphere, the mercury in the barometer will be highest when the heat is greatest; a correction is therefore necessary for this source of error, before the exact effect of the pressure can be ascertained, and this is accomplished by means of the thermometer, or instrument for measuring the degrees of heat, joined with a knowledge of the rate at which the mercury in the barometer expands.

The state of the amosphere, with respect to dryness or moisture, is measured by an instrument called an *hygrometer* or *hygroscope*. Various substances are susceptible of considerable alterations in weight or length, by attracting or parting with moisture; such substances are called *hygroscopic*.

The quantity of water returned by the atmosphere to the earth in the state of rain, is ascertained by an instrument called a *pluviometer* or *rain-guage*. It is usually made in the form of a jar, or hollow cylinder, with a funnel at the top of it. They are made of various sizes, but in general, if the ring be twelve inches in diameter it may not be considered too large.

WINDS.

Air, when in progressive motion, is called wind, in which state it becomes one of the most powerful agents in nature, its force increasing nearly as the square of its velocity, and its velocity often being prodigious.

The natural tendency of the atmosphere as of all other bodies, is to remain in a state of rest; and if this tendency were not checked by unceasing causes, this fluid would everywhere be stagnant, and at the same elevation would have the same. The density of air is diminished by an increase of temperature, that is, the more it is heated, the more space it takes up, and consequently the less is its pressure, bulk for bulk, on the surrounding air. This being the case, and the contrary, when its density is increased by cold, being equally true, it follows that when any particular tract of air is heated or cooled more than the rest, the heavy parts will press it upwards, and occupy its place; and the atmosphere will not be at rest, until the equilibrium of its parts, in heat and density take place.

Dr. Franklin was the first who observed, that winds originate at the precise point towards which they blow. Thus, in going out of a large town in winter, a wind is met in every point of the compass, beause the air in the town being rarified by so many fires and the breathing of the people, is forced to ascend by the pressure of the colder and denser air of the country on all sides of it. Partial changes of temperature, are, therefore, the chief general causes of all winds, and it is the business of man, with respect to this subject, to discover where, and in what degree, they occur, in order to account for the individual phenomena. The attraction of the sun and moon is on good grounds supposed to occasion wind, and it is calculated from the theory of gravitation, that the influence of these bodies in their daily motions, is sufficient to produce a continual east wind about the equator. When, therefore, attraction coincides with heat to produce an aerial tide, the combined effect may be very considerable. Whatever may be the influence of

the sun and moon in occasioning winds by their attraction, that of the moon will be the greatest, for the same reason, and in the same proportion, that her influence is the greatest in producing the tides of the ocean. The most likely periods of the year to have high winds are the two equinoxes; and storms are more frequent at the time of new and full moon, especially those new and full moons that happen about the equinoxes.

The most remarkable of all the winds is called the *Trade-wind;* and as it evidently follows the course of the sun, it appears undeniable that the sun is the cause of it. This wind, about the middle part of its track, always blows either exactly or very nearly from the east; but even when the sun is at, or very near the equator, towards its northern boundary, it deviates more and more from the east towards the north; and towards its southern boundary, it deviates more and more from the east towards the south. The manner in which the sun causes the trade-wind, seems to be generally agreed upon.

Of the periodical winds, the most remarkable are those called the *Monsoons,* which blow for six months in one direction, and for six months in an opposite one. They are confined to the tropics, and are deviations from the regularity of the trade-winds of half a year's duration, because for half the year, the monsoons mostly coincide with the general trade-wind. The origin appears to be owing to the circumstances of the different degrees of heat communicated to the air by water, and particular tracts of land. From October till April, the monsoon sets in from the north-west to the south-east, opposite to the general course of the trade-wind on the other side of the line; and here also the general trade-wind resumes its usual course during the other months, which constitute the winter seasons in these regions.

Some of the variable winds which prevail in warm countries, are distinguished by particular names, and possess very extraordinary qualities. The *Harmattan* is a wind which blows from the interior parts of Africa towards the Atlantic ocean. It prevails in the months of December, January, and February; but its duration is uncertain, sometimes only a day or two, sometimes as many as fifteen or sixteen. It is always accompanied

with a fog that robs the sun of his splendour. Such is the extreme dryness of this wind that it withers the whole vegetable creation. The human body is much affected with the harmattan, which if it continues five or six days, the scarf skin peels off, and though the air is cool, it excites a troublesome sensation of pricking heat. Notwithstanding, the harmattan is salubrious, stopping infection, and removing the virulence of distemper, with an efficacy not less remarkable than its other qualities.

The *Sirocco* is a south wind, which generally blows in Italy and Dalmatia, every year about Easter. It is supposed to blow from the burning deserts of Africa.— During its continuance, the inhabitants of the countries where its prevails, never venture out of doors unless compelled by necessity, but closing every aperture that can admit the air into their houses, they keep continually sprinkling their apartments with water. In Sicily this wind seldom continues longer than thirty-six or forty hours; in Italy it sometimes continues twenty days, but is not so severe. It is commonly succeeded by the tramontane, or north wind, which in a short time restores the vigour of languishing nature.

The *Samiel*, or mortifying wind of the deserts cannot, it is said, be breathed without destruction. The camels are reported to be instinctively aware of its approach, and to thrust their heads under the sand till it is blown over, which is commonly in a few minutes. The travellers throw themselves flat on the ground to avoid it; but if any one breathe it, his whole body becomes immediately mortified.

Whirlwinds are generally supposed to be occasioned by the conveyance of winds from all parts to one point, by some extraordinary rarefaction of the air at that point. The currents acquire by their conflict at the place of meeting, and the velocity with which the rarified air rushes upwards, a centrifugal force, which causes them to recede from the axis of rotation..

A *Tornado* is a whirlwind upon a large scale, being produced by the same causes; it is the whirlwind of tropical regions, and its effects are often tremendous. A moist vapour usually attends a tornado, the path of which is marked as if with rain.

Hurricane is another term for a storm wind, seldom

seen, in its most terrific form, except in tropical climates. It is occasioned by the struggle of opposite winds, but does not, like the tornado, shift through all the points of the compass. It generally comes on with a northerly wind, and after veering to the east, it ceases; but the change is effected with such sudden impetuosity, that no ship can veer with it; whence it happens that the sails and yards are carried away, and sometimes the masts themselves twisted off. Of hurricanes it is usually observed that they happen either on the day of the full, change, or quarter of the moon.

It would be an interesting speculation to attempt the developement at large of the purposes effected by the winds; but in this place it must suffice to observe generally, that their cessation would accomplish the immediate destruction of animated existence. It is the atmosphere's ceaseless propensity to motion, from every cause that varies its density, and the universal prevalence of such causes, that carries off noxious effluvia as it is produced, to parts where, by chemical operations in the laboratory of nature, it is absorbed or regenerated, and the whole mass of atmosphere preserved from corruption. And when we turn from this point of view to another, we find the services of the winds almost equally important in ameliorating the fervour of a vertical sun, and in short, equalising the temperature over the whole globe. When these salutary and universal benefits are considered, the transient and partial effects of storms, especially when regarded as arising out of the rapidity with which the winds perform their office, can be regarded only as a slight sacrifice to the general good.

THE WEATHER.

A knowledge of the approaching changes of the weather is of so much utility and importance to a great part of mankind and of convenience to all, that it may seem surprising every indication of change observation has yet furnished, has not been accumulated, and reduced into one system. It is true, however, that with respect to this, as on other occasions, those most interested are

willing to content themselves with arguing from the appearances of the passing moment, or from a set of rules which, almost without effort, they have formed for themselves. It is to be admitted that farmers, and a great number of others, are generally furnished with a barometer or weather-glass; but this instrument from its indications as to height not being combined with other circumstances is seldom of much use to them, and not unfrequently leads them into errors, which might have been avoided, under a more comprehensive consideration. Dr. Hally appears to have been the first who drew up, from an extensive series of observations, the laws which govern the motions of the barometer, and it is to his conclusions we shall here advert. He states the most general phenomena in eight propositions.

1. In calm settled weather, when the air is inclined to rain, the mercury is commonly low.

2. In serene, good, settled weather, the mercury is generally high.

3. Great winds, though not accompanied with rain, sink the mercury lowest of all, with relation to the point of the compass the wind blows upon.

4. The greatest heights of the mercury are observed during easterly and north-easterly winds.

5. In calm, frosty weather, the mercury generally stands high.

6. After great storms of wind, when the mercury has been low, it generally rises again very fast.

7. The more distant places are from the equator, the greater the range of the mercury in the barometer.

8. Within and near the tropics, the variation of the mercury is very little in all weathers.

Hence he considers the principal cause of the rising and falling of the mercury to be variable winds which are found in the temperate zones, and which in England are remarkably inconstant. A second cause is the uncertain exhalation, and precipitation of the vapours lodging in the air, which is thereby rendered heavier or lighter; but this cause is in a great measure dependant upon the former; but it will now be necessary to state more minutely the particular states of the weather which are likely to follow such changes.

1. The rising of the mercury generally presages fair

weather, as its falling does the contrary, or rain, snow, high winds and storms.

2. In very hot weather, the sudden falling of the mercury portends thunder.

3. In winter, the rising indicates frost; and in frosty weather, if the mercury falls three or four divisions, there will certainly follow a thaw; but if it rise in a continued frost, it will be accompanied with snow.

4. When foul weather quickly succeeds, after the falling of the mercury, it will not be of long duration; nor are we to expect a continuance of fair weather when it soon succeeds the rising of the mercury.

5. If, in foul weather, the mercury ascends considerably and continues in an advancing state for two or three days successively, before the foul weather is over, then we may expect fine weather of some continuance.

6. If, in clear weather, the mercury falls remarkably for two or three days together, before the rain sets in, it is highly probable that much rain, and perhaps high winds will follow.

7. An unsettled state of the mercury indicates changeable weather.

8. The mercury sometimes falls considerably without any remarkable change following it, this may arise from a distant storm, or even an earthquake.

9. If the mercury begin to rise steadily from a low state, and the wind change from the south or west, to the north or east, fine weather may be expected.

10. A rapid movement of the mercury, even when rising, is an indication of bad weather, though not of long continuance.

11. The rising of the barometer is a more certain indication of fair weather, than its sinking is of rainy weather; because it so often sinks for wind as well as rain. If, therefore, while the barometer is sinking, the atmosphere still remain clear, wind may be expected.

With respect to prognostics of the weather independent of the barometer, and which indicate the general state of an approaching season, Kirwan has deduced the following rules from observations made in England during a period of 112 years.

1. When no storm has either preceded or followed the

vernal equinox, the succeeding summer is in general dry, or at least five times out of six.

2. If a storm happen from an easterly point, on the 19th, 20th, or 21st day of May, the following summer will four times in five be also dry. The same event generally takes place, if a storm arise on the 25th, 26th, or 27th, days of March in any point of the compass.

3. Should there be a storm, either at south-west, or at west-south-west, on the 19th, 20th, 21st, or 22nd of March, the following summer is wet five times out of six.

To these prognostics of the weather might be added many others; but, perhaps, the list has been already sufficiently extended. The work of observation, on all the changes of the atmosphere that can be detected by instruments, is now carrying on, to an extent without example in former times; and it is only as these come forward that prognostics of real value can be multiplied.

SOUND.

The only remaining mechanical property of air which we have to notice, is that which renders it the medium of *sound*.

Any body which produces sound by collision from another, is called a *sonorous* or *sounding* body; though the term sonorous is more especially applicable to such bodies as produce a distinct and continuous sound, like a bell, or the string of a musical instrument, than to those which produce a dull and momentary sound like that of clashing together two pieces of chalk.

The velocity of sound, though the subject of different opinions, has been examined with considerable success, and on the authority of numerous experiments, it is supposed to travel uniformly at the rate of about 1,142 feet in a second, or one mile in rather less than five seconds. All sounds move with the same velocity; the gentlest whisper moves over the same distance to which it extends, as rapidly as the report of a cannon over the same distance.

An orator, with a good voice, may easily make himself heard at the distance of one hundred feet in a direct line before him; but he will not be heard with equal distinctness at more than the distance of eighty feet on his right and left: or of forty feet immediately behind him.

A knowledge of the velocity of sound is obviously applicable in certain cases, to the purpose of determining distances. If a vessel is observed to fire a gun, and eight seconds elapse between seeing the flash and hearing the report, the distance of that vessel is 8 times 1,112 feet, or 1 mile 1,285 yards; because the flash and the report in reality happen together, and the velocity of light is so great, that, at any terrestial distance it may be considered instantaneous. In the same manner may be estimated the distance of thunder, by noticing the number of seconds that intervene between seeing the lightning and hearing the thunder.

When smooth and level ground is interposed between the sounding body and the hearer, the sound is heard at a much greater distance, than when houses, walls, trees, crops of grain, &c, are interspersed in the path of sound. Over the surface of smooth water, sound is conveyed admirably well, and may be heard at a greater distance than in any other way which nature affords. By placing the ear close to the ground, or to the water, distant sounds may be heard which would otherwise be imperceptible. The inhabitants of uncivilized countries understand this practice.

The vivacity with which sounds are transmitted through solid substances is very remarkable. The scratch made with a pin at one end of a piece of timber, fifty feet long, may be distinctly heard by an ear placed close to the other end, although the same could not be heard through the air at the distance of a dozen feet.

When the air, in a state of vibration, strikes upon a solid regular surface, it is reflected by it in the same state, at an angle equal to the angle of incidence. An ear, therefore, situated in the direction of these reflected vibrations, perceives a sound similar to the original one, but apparently originating in a right line with its last direction, equal to the reflected and incident course. These reflected sounds are called *echoes;* they cannot on account of the great velocity of sound be distinguished

from the original sounds within the space of fifty-five feet from the reflecting surface, therefore, an echo must always be at that distance: when the reflecting surface is nearer, it is only said to increase the sound. As reflecting surfaces produce various differences, according to their distance, figure and composition, the effects of echoes are very different.

"It is in general known," says Goldsmith, "that caverns, grottoes, mountains, and ruined buildings return this image of sound. Image, we may call it; for in every respect it resembles the image of a visible object reflected from a polished surface. Our figures are often represented in a mirror without seeing them ourselves, while those standing on one side are alone sensible of the reflection. To be capable of seeing the reflected image of ourselves, we must be directly in a line with the image. Just so it is in an echo, we must stand in a line in which the sound is reflected, or the repetition will be lost to us, while it may, at the same time, be distinctly heard by others who stand at a small distance to the one side of us. I remember a very extraordinary echo, at a ruined fortress near Louvain, in Flanders. If a person sung, he only heard his own voice, without any repetition; on the contrary, those who stood at some distance, heard the echo, but not the voice; then they heard it with surprising variations, sometimes louder, sometimes softer, now more near, then more distant."

HYDROSTATICS AND HYDRAULICS.

The science of Hydrostatics treats of the pressure and equilibrium of fluids in general; but it is chiefly exemplified by the developement of the mechanical properties of water, excepting so far as this fluid is dependent for its effects upon its motion. The science which teaches the laws of fluids in motion, and the application of fluids in that state to machines is called *Hydraulics*. This distinction between Hydrostatics and Hydraulics, appears to make two sciences of subjects too intimately connected to be considered in any other light than as including only different parts of the same subject. We have, therefore, classed them together, and shall regard them as convenient heads for different chapters, on the properties common to fluids.

HYDROSTATICS.

A fluid is a body whose particles yield to the least effort of partial pressure. Fluids are of two kinds, *elastic*, and *non-elastic*. Elastic fluids are those in a state of air or gas; their bulk varies with the force compressing them, and in their other mechanical properties they resemble common air; the general laws relative to them are, therefore, to be derived from pneumatics. Non-elastic fluids, as oil, water, spirit, or wine, are either absolutely or very nearly incompressible. These are the bodies with which hydrostatics are chiefly concerned.

The cause of fluidity has been the subject of much speculation, but one opinion is, that the particles of fluids are spherical, in consequence of which configuration they slide over and among each other with prodigious facility.

This assumption cannot be affirmed by experiment; no microscope being powerful enough to show the component particles of any fluid, but it is favoured by the proofs we have of the numerous interstices of fluids; in water, for example, salt and various other bodies may be dissolved in considerable quantity without enlarging its dimensions. According to this theory, also, the densities of different fluids are accounted for, by supposing their spherical particles to be of different sizes, the densest fluid having always the least particles; but why the particles of various solids should assume a spherical figure by the action of fire, which fuses them, and some other figure when these bodies become solid in cooling, is not so easily determined. It is, therefore, the opinion of others that fluidity is simply the consequence of the caloric (heat) combined with different bodies; the caloric surrounding these particles and lessening their cohesion so much that they slide very easily over each other; when, however, so much caloric is abstracted, that the attraction of cohesion can operate, fluids become solid. Perhaps this theory would be improved, if the former were combined with it, rather than wholly rejected. Caloric, it may be supposed, will most easily lessen the attraction of cohesion between particles perfectly spherical, because these have the fewest points of contact; bodies may, therefore, be more or less easily rendered fluid, in proportion as their particles differ more or less from the spherical figure.

Though the particles of fluids have certainly a very small degree of cohesion to each other, yet it is not so small but that it may in a variety of instances be rendered visible; for example, it is the attraction of cohesion that prevents a drop of water, placed gently on any dry surface, from extending itself; and that allows a vessel to be filled above its brim with water, which could not happen if water were a perfect fluid.

The Academy of Florence inferred the total incompressibility of water; but Canton established some conclusions which showed that the inference drawn by the Florentines was not to be accepted without limitation.—He found that water expended one part in 21,740, when the pressure of the atmosphere was removed, and submitted to a compression of one part in 10,870 under the

weight of a double atmosphere. He also observed that water possessed a most remarkable property of being more compressible in winter than in summer; contrary to the effect on spirits of wine and oil of olives. It remains, therefore, for future investigation to fix the judgment of philosophers on this subject; in the meantime, even granting all the compressibility that has been contended for, the quantity of it is too small to be noticed in practice.

Persons at sea frequently try an experiment which proves in a great degree the incompressibility of water. Having corked a bottle containing only air, and therefore called empty, they tie a rope to it, and sink it to a considerable depth by a sufficient weight; on pulling up the bottle, they generally find it either broken, or the cork forced in: but on sinking to the same, or any greater depth, a bottle filled with water, they find it, when drawn up, to be uninjured, because the water resists compression, and therefore supports the bottle; which support, under the pressure at a great depth, the air cannot supply.

Fluids, as well as solids, press downwards by gravitation, according to their quantities of matter, endeavouring always to attain the lowest place possible, or place nearest the centre of the earth; but they have this peculiarity, that they press in every direction alike, in proportion to their perpendicular height, and not their quantity. It is from this property of pressing in every direction, that the sides of vessels containing fluids, although at rest, must be made strong like the bottom; or if any difference be made, it must be gradual towards the top, because the pressure diminishes with the diminution of the column sustained.

The downward pressure of water may be proved, where wood and other bodies lighter than water refuse to swim. Take two pieces of wood, planed so perfectly flat, that when put together no water can get between them; cement one of them to the bottom of a jar, or any vessel capable of holding water; place the other piece upon the one so cemented down, the two flat faces of course being in contact. Press upon the upper piece with a stick, to prevent its moving while the vessel is filled with water; after which, the stick being with-

drawn, the loose piece of wood will remain in its situation, as steadily as the piece cemented down, because it is pressed by all the weight of the water over it; but if it be raised, however little, at one edge, some water will then get under it, which being acted upon by the water above, will immediately press it upwards, and from its lightness it will reach the surface.

On the disposition of water to press upwards to the level of its source, depends the existence of springs, which always originate in higher situations than those in which they are found. Of this property the ancients appear not to have been aware. When they had water to convey from one hill to another, they were at the expense of constructing an immense aqueduct to cross the valley in a right line from the source, without reflecting how commodiously the same might be effected by a pipe.

From the pressure of water being as its perpendicular height, it becomes necessary to guard against its effects in the construction of canals and other reservoirs; for when a column of water insinuates itself under a bank, if its upward pressure exceed the resistance of the weight upon it, which might frequently happen, the bank will be destroyed. Such accidents are prevented by lining the bottoms of the reservoirs with clay, or some material impervious to water.

SPECIFIC GRAVTY.

The expression, specific gravity, is of very frequent occurrence in scientific works; the explanation of it, and the method of determining the specific gravity of any body, forms an important branch of hydrostatics.

The specific gravity of a body is simply the expression of its weight, when compared with an equal bulk of distilled water. For example, the specific gravity of gold is to the specific gravity of water as 19 to 1; the meaning of which is, that a given magnitude of gold, for example, a cubic inch, will weigh nineteen times as much as the water that could be contained in a vessel

the capacity of which is precisely equal to one cubic inch.

When a solid body is wholly immersed in a fluid, or as the fluid presses upon and touches it at every point, it is evident that the quantity of fluid displaced must be precisely equal to the bulk of the body immersed in it: consequently it follows that the greater the density of the body, that is, the greater its weight for its bulk, the less will be the quantity of fluid which any given weight of it can displace.

When a body sinks in a fluid of its own accord, it is because of its being heavier than an equal bulk of that fluid, in consequence of which it overcomes the upward pressure by which it is opposed; this upward pressure, supposing the fluid to be water, is equal only to its bulk of that fluid, and, therefore, after deducting the weight of its bulk of water, the remainder is the force with which it sinks. Thus, if the weight of a body be three ounces, and the weight of its bulk of water be one ounce, it will sink in water with a weight of two ounces. This accounts for the differeent degrees of rapidity with which different bodies sink.

From the above remark, that the force with which a body sinks in water is less than what it weighs in the open air, by the bulk of the water it displaces, this hydrostatical axiom is plainly deducible, that every body immersed in water, and every other fluid, loses just so much of its weight as equals the weight of an equal bulk of the water or other fluid. A knowledge of this truth renders the most admirable assistance in detecting the identity of substances, when all other characteristics, that can be conveniently resorted to, prove ineffectual; of this a remarkable example and illustration immediately resulted from its first discovery, which happened in the following manner:—

Hiero, King of Syracuse, had employed an artist to make him a regal crown of gold, and had furnished a sufficient quantity of pure metal for that purpose. When the crown was brought home its weight was found to be equal that of the gold delivered for it, yet the King suspected an adulteration. He applied to the celebrated Airchimides for the means of detecting the amount of the fraud; the philosopher could not for some time arrive at

any satisfactory conclusion, but at length an accidental observation which he made, reminded him of the means he might employ. When stepping one day into a bath, he took notice that the water rose in proportion to the quantity of his body immersed in it, and immediately reflecting that a body of equal bulk with himself would raise the water in the same degree, though a body of equal weight, but not of equal bulk would not raise it so much, he became instantly alive to all the consequences of this reasoning, and in the ecstacy of the moment, without recollecting his clothes, he ran into the streets of Syracuse, exclaiming "I have found it! I have found it!" He forthwith took masses of metal, each of them equal in weight to the crown, but one of them was of pure gold, the other of silver. These he separately let down into a vessel containing water, the rising of which by the alternate immersion of the masses, could easily be determined by measure. He found that the silver displaced a greater quantity of water than its weight of gold; he then tried the crown, and found that it displaced more water than its weight of gold, but not so much as its weight of silver. By these means he discovered that the crown was not made of pure gold, and by comparing his observations on the bulk of water displaced by the crown, the gold, and the silver, he discovered the quantity of gold the crown actually contained.

As whatever weight a body is found to lose, on being weighed while suspended in water, is the same as a quantity of water equal to its bulk; hence to obtain specific gravities, it is not necessary to reduce solids to any given size, in order to compare them by measurement, but they are taken of any size or figure, and weighed first in air, and then in water, by means of a hydrostatic balance.

THE DIVING BELL.

The nature of the diving-bell may be easily understood by reflecting on the facility with which air may be retained under water, in vessels open only at the bottom, because, like any solid, it prevents other bodies from occupying the place it occupies itself. Thus if we take a glass tumbler, or any similar vessel, and holding it inverted, push it vertically downwards into the water, the air it contains will not escape, and the water at inconsiderable depths, will scarcely rise at all within it. It is clear, that whatever were the size of the vessel, the water would in the same manner be excluded by the air, and as the air is the same as that of the atmosphere, it is equally clear, that in a vessel of sufficient size, men might be stationed without being incommoded by the water, as they could breathe the air and live till its vital principle was exhausted. If then any means were contrived to remove the contaminated air, and to send down a fresh supply of fresh air, they might remain under water any length of time that they chose, and if let down by a rope, to a wreck, or to the bottom of the sea, they might perform any work of which the size of the vessel admitted, or to which they were competent on land. The vessel used for this purpose is called a bell, because it is much in the form of a truncated cone, and often resembles a bell in its general appearance. It must be mentioned, however, that the water in proportion to the depth to which the bell is sunk, rises within it, by the increase of its pressure; and compresses the air. At the depth of thirty-three feet under water, the water presses into the bell with the power of a double atmosphere, and the air, which, when it was at or very near the top, occupied the whole interior capacity, does not then occupy more than half of it, consequently the bell becomes half full of water; and at all greater depths the air sustains a proportionably greater compression, the water at the same time rising as this effect goes on, till at length it covers the divers.

Dr. Halley was the the first person who materially

improved the diving-bell. He formed a machine of this kind of copper in the form of a bell; and weights of lead were distributed about the lower part, to keep it in an inverted position, while they rendered it at the same time specifically heavier than its bulk of water, and consequently it would sink by its own weight. It was three feet wide at the top, five feet at the bottom, and eight feet high. In the top was a window of very thick glass and also a stop-cock, to let out the hot air which had been breathed; and within the bell was a circular seat for the divers. To supply the divers with air, two barrels of about sixty-three gallons each, cased with a sufficient quantity of lead to make them sink, were prepared to be sent down to the divers. The bung-hole in each barrel was left open, and kept on the under side, to let in the water as the air in the barrels condensed during their descent, and to let the water out again when they were drawn up. To a hole in the upper side of the barrels, was fixed a leathern pipe, well prepared with bees' wax and oil, which was long enough to fall below the bung-hole at the bottom, and kept down by a weight in such a way that the air in the upper-part of the barrels could not escape, unless the lower end of these pipes were first lifted up. These air barrels, by means of proper tackle, were made to rise and fall in succession, like two buckets in a well; in their descent they were directed to the divers by ropes fastened to the under edge of the bell, and one person held himself always in readiness to receive them, and by taking up the end of the pipes above the surface of the water in the bell, the water by its pressure filled the barrels, while the air they contained rushed into the upper part of the bell. As soon as one barrel was discharged, by a signal given it was drawn up, and another sent down; thus a continual supply of fresh air was supplied to the divers. Meanwhile, as the cold air rushed into the bell from the barrel, it expelled the hot air at the top where the stop-cock was opened for that purpose. Dr. Halley was himself one of five, who who went down together in his bell; they remained at the bottom, at the depth of ten fathoms, for an hour and a half without experiencing any ill effects, and might have continued any length of time that they chose. The window in the top of the bell let

in so much light, that when the sun shone, and the sea was unruffled, they could read and write with great ease, and could see the pebbles or take up any small objects that happened to be at the bottom; but every thing they saw appeared red. By writing with pieces of sharpened iron upon small pieces of lead, which they sent up with the returning air-barrel, they maintained a communication with those above, and directed the bell to be moved as they desired. In misty weather, and when the sea was rough, it was nearly dark in the bell, and it became necessary to burn a candle, which consumed as much air as one person. The divers in descending with this bell, felt a pain in their ears; as if the end of a quill had been thrust into them. This sensation was owing to the pressure of the condensed air upon the tympanum; it went off gradually as the air in their bodies became as dense as that without. It appears by this account, that the pressure of a double or even threefold atmosphere is much more endurable than the diminution of the ordinary pressure to half a single atmosphere.

The main rope by which a diving-bell is supported, ought to be soaked in water before it is used; or it would perhaps be still better if a chain were substituted. An instance occurred in the bay of Dublin, where the rope, in suffering the contraction which water always occasions, caused a diving-bell to turn round, by which means the signal strings were entangled. The people above, not receiving the expected signals, drew up the bell; but they were too late; the two men it contained were both dead; not drowned, but suffocated by the want of a supply of fresh air.

Another circumstance proper to be attended to, in using a diving-bell, is to lower it very gradually through the water, to prevent the injurious effects which the abrupt condensation of the air contained in it might have upon the men.

HYDRAULICS.

We will now consider the objects of hydraulics, which relate to the laws and uses of fluids in motion. Here, as in hydrostatics, though the doctrine laid down might be applied to fluids in general, allowing for differences in density, yet water is the fluid constantly referred to; because it is the fluid with which men are most extensively concerned, and elucidations specifically applied give greater precision to the subject.

MOTION OF WATER FLOWING OUT OF RESERVOIRS.

When a vessel, containing water, and open at the top, is pierced below the surface of the fluid, the velocity with which the water flows out is observed to be greatest at first, and to diminish gradually as the water sinks, and the nearer the aperture is to the bottom, the greater the quantity which flows out in a given time. From a hole on a level with the bottom of the vessel, the water would emerge with nearly the same velocity as if it were in the bottom. This egress of fluids from the perforated sides of vessels, is a consequence and a proof of their pressing in every direction; and the law, which governs the rate of it, is an admirable illustration of the harmony which distinguishes the operations of nature; although our limited powers are but occasionally competent to its developement: the velocity with which water flows out of an aperture at the side or bottom of a vessel, is as the square root of the distance of the aperture from the surface of the water. This is but saying in other words, that the velocity is according to the pressure or force which occasions it, and it has already been demonstrated that the pressures of fluids is as their perpendicular heights. In order therefore that

double the quantity of water may flow through one hole that flows through another of the same size, the former must be four times as far from the surface as the latter; and if a supply of three times the quantity of water be required, without changing the size of the aperture, three times the velocity must be produced, and three times the velocity will require nine times the pressure; consequently the hole must be nine times as far from the surface of the fluid, as that which only produced a third of the supply. An experiment in proof of these positions is easily made: let two equal pipes be fixed into the side of a vessel containing water, but one of them at four times the distance from the other from the surface: let the pipes be allowed to run at the same moment, while water is constantly poured into the vessel, and kept at the same height in it during the experiment. Then if a cup that holds a pint be so placed as to receive the water that spouts from the upper pipe; and, at the same time, a cup that contains a quart, be placed to receive the water from the lower pipe, both cups will become full at the same moment.

The horizontal distance to which a fluid will spout from an aperture, in any part of the side of an upright vessel, below the surface of the fluid, is equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe to a semi-circle described upon the altitude of the fluid; and therefore, the distance will be the greatest possible when the mouth of the pipe is at the centre of the semi-circle; because a perpendicular to its diameter (supposed parallel to the side of the vessel) drawn from that point, is the longest that can possibly be drawn from any part of the diameter to the circumference of the semi-circle.

The progress of water through a pipe is greatly retarded by every deviation from a straight direction, and by every enlargement, contraction, projection, or roughness it meets with in its passage; and most of these irregularities are of too variable a nature to be submitted to regular calculation. They operate in occasioning eddies or contrary currents, in counteracting which part of the moving force is inevitably lost. To avoid as much as possible the retardation from flexure, when it is

necessary to give a new direction to a pipe, the point of flexure should not be sharp, but take as comprehensive a sweep as can be allowed.

MOTION OF WATER IN RIVERS, AND WAVES.

The motion of a river is in general produced by gravitation, which obliges the water to descend from a higher to a lower situation; and therefore it is swift or slow according as the descent or inclination of the bed of the river is great or small. Sometimes, or in some parts of rivers, the motion is produced by pressure, or disposition of the water to spread itself out, in which case it increases with the depth.

To ascertain whether the water of a river, almost horizontal, flows by means of the velocity acquired in its descent, or by the pressure of its depth, set up a stake perpendicularly in it, then if the water rise and swell immediately against the stake, it is the descent which occasions its motion; but if it first stop a little, it is impelled by pressure.

A very simple mode of ascertaining the mean velocity of a stream, consists in the use of a pole of light wood, about the same length as the depth of the stream; the lower end of this pole is loaded, so that in the water it will remain in a vertical position, with its upper end near the surface: the preparation is finished by fixing in the upper end, exactly in the direction of its axis, a slender rod to project above the water. This pole being placed in a river, the rod will point up or down according as the stream is swiftest at the surface or near the bed; and the rate of its motion, in any given space of time, will be the mean velocity at that place.

The waves formed on water by the action of the wind, are superficial oscillations of the fluid that are by no means so irregular in their action as might be inferred. The first impression of the wind upon the water is to produce a cavity; this cavity cannot be produced without heaping up the water before it; the water thus

heaped, having attained an elevation proportionate to the force which caused the depression, sinks down towards its level, but in thus sinking down, it acquires a velocity which carries it below its level; by this means it produces a depression like that caused by the wind in the first instance, and thus successive waves are propagated, but the motion diminishes in proportion to the distance over which the force extends.

The depth to which the sea is agitated, even in violent tempests, is not very considerable; at the depth of twenty feet below what is the level in a calm, the effect is very slight, and at thirty feet it would probably be altogether imperceptible. It may therefore seem difficult to account for the mountainous waves encountered by seamen; but it must be remembered that the wind is constantly acting, and that one wave is raised on the top of another, till the accumulation becomes prodigious.

When a stone or any other body is thrown into a vessel containing oil, it agitates the surface nearly as much as if thrown into a like quantity of water; but the power of the wind on a surface of oil is exceedingly small, and incapable of producing more than a slight undulation. A quantity of oil in the proportion of an ounce to an acre poured out on the windward side of a lake, will spread itself over the whole surface, and still the waves raised by the wind.

HYDRAULIC MACHINES.

There are many machines for hydraulic purposes which the limits of this volume will prevent us from giving little more than their names and uses; but this is the less to be regretted as they are in general so well known that a short notice of them here will suffice.

The common pump with which water is drawn out of wells is usually called a *Sucking-Pump*. This appellative originated at a period when the effect was attributed to suction, and ought to have been rejected when the pres-

sure of the atmosphere was proved to be the efficient agent in causing the water to rise.

The velocity of the stroke of a pump should never be less than four inches, nor greater than two or three feet in a second; the stroke should be as long as possible, to prevent loss of water by the frequent alternations of the valves. The diameter of the suction-pipe is best proportioned, when it is from two-thirds to three-fourths of that of the barrel.

The *Lifting-Pump* is generally used for great water-works, and where the water is not to be brought up from any great depth. It is variously constructed, but in general the upper valve is fixed, and the lower one moveable; and the water is, in fact, lifted, as if it were in a bucket; the sides of the bucket being formed by the barrel, and the piston forming its bottom.

The *Forcing Pump* is furnished with two valves, which are both stationary, or open and shut in the same situation. A forcing pump is the essential part of an engine for extinguishing fires. These engines have generally two forcing pumps, and the pipe for the air vessel, except at the extremity, is made of leather, or some pliable material, that the jet may be easily directed to any given point.

The *Screw of Archimides.*—This useful invention originated with the famous Archimides of Syracuse. It is formed by wrapping a tube round a cylinder, in the form of the thread of a screw. The cylinder is suspended upon pivots, and turned by means of a winch; its position is inclined to the horizon, with its lower end in the water to be raised. The tube or spiral is open at both ends, and when, by turning the winch, the lower orifice strikes the water, the water gradually rises in the tube till it is at last discharged at the upper orifice. When the water is raised out of a river by means of this screw, if a wheel with float-boards be attached, the screw will be wrought by the stream itself.

This screw has been successfully used to propel steam-boats in place of the paddle-wheels.

The *Rope Pump.*—If a pulley, set in motion by a large wheel, is fixed in a suitable frame over the mouth of a well, while another pulley is situated in a similar situation in the water of the well, and an endless rope passes over both pulleys; on revolving the large wheel, every

part of the rope will successively dip into the well, and after attaining the top of the upper pulley, will, in descending, throw off, by its centrifugal force, a portion of the water it has imbibed, the quantity of which, when the rotation is quick, will be very considerable.

The *Hydraulic Press.*—This is a very useful invention for those who require great pressure, such as packers, printers, &c. It occupies very little space and may be made several hundred tons pressure, which can be applied at any time by a boy.

The *Steam Engine.*—The first person who entertained the idea of employing steam as a motive force, is not certainly known; but the earliest application of steam to this object, is not carried further back than the year 1629, when an Italian, called Brancas, published an account of an invention of his, in which steam ejected from a large æolipile was the force that wrought a stamping engine. Thirty-four years afterwards, in 1663, the Marquis of Worcester, a nobleman of great ingenuity, published a little work, called "A Century of Inventions," in which one hundred contrivances of his own were enumerated; the account he furnishes of each is short, and often very obscure; with the latter fault is particularly chargeable, the description he furnishes of an engine for raising water by the force of steam. At this day we have no means of certainly knowing whether the discovery of Brancas was known to the Marquis or not; but it is not suspected that he was acquainted with it, and therefore the English are inclined to consider the original idea of the steam engine as having arisen in their own country: the French on the contrary, claim it for themselves, and bring forward the name of Papin, but Papin's application of steam as a motive force was not published till 1690, which was twenty-seven years after the Marquis of Worcester's publication. But let it even be supposed, that for Brancas, the Marquis, and Papin, the claim to independent and original invention could be substantiated, yet the Italians and the French have no claim to notice afterwards, for following up the ideas of their countrymen; it is solely to the English that the world is indebted for rendering the steam-engine what it now is, the noblest machinery ever invented by man;—the pride of the machinist,—the admiration of the philosopher. Animals require long and frequent periods of

relaxation from fatigue; and any great accumulation of their power is not obtained without great expense and inconvenience; the wind is changeable to a proverb; and water, the constancy of which is in few places equal to the wants of the machinist, cannot in general be obtained on the spot where other circumstances require machinery to be erected. To relieve us from all these difficulties, the last century has given us the steam-engine for a resource; the power of this assistant may be accumulated indefinitely; it requires but little room; it may be erected in all places; and its mighty services are always at our command; whether in winter or in summer, by day or by night, it knows of no intermission but what our wishes dictate. But we must forbear as we could fill a volume on this subject.

AEROSTATION.

THE principles and practice of the art of navigating the atmosphere is called aerostation.

The general terms for the machines used in this act, is that of *Aerostats*, or *Aerostatic* machines; but those which are of a spherical figure, and filled with gas, are better known by the name of *Air-balloons*. The person who takes a voyage in one of these is called an *Aeronaut*.

The art of ascending into and navigating through the air appears at all times to have been an object of fond speculation; but the most exact inquiry has not shown that it was any other than a romantic hope till so lately as the year 1782. The first aerostatic attempts were directed towards an imitation of the motion and flight of birds, but these proved abortive, when muscular exertion was depended on, because the muscles which could be brought into action, were altogether insufficient to give motion to wings of a suitable size: and when machinery was thought of, the weight of materials and complexity of construction necessary, appeared to be insurmountable barriers to success. Still there was one avenue to the object of pursuit, to which the common and well known principles of hydrostatics appeared to direct the way, though it had been of all others the most neglected; this was the obvious one, that any body which is specifically, or bulk for bulk, lighter than common air, will rise and swim in it and submit to the action of the wind; therefore, if any body could be found which was in any considerable degree lighter than air, by making it of a sufficient size, a person might attach himself to it, and float along with it. But as air was considered the lightest of all things, there appeared little reason to believe that such a discovery would be made, till, in the year 1766, Henry Cavendish announced to the world, that the gas, now generally called hydrogen, but at that time called

inflammable air, was at least seven times lighter than common air. In consequence of this discovery, it occurred to Dr. Black, and he mentioned it in his lectures, in 1767 or 1768, that if a bladder sufficiently light and thin, was filled with this air, it would form a mass so much lighter than the same bulk of atmospheric air, that it would float in the latter. He proposed to use the allantois of a calf for this purpose, but other avocations prevented him from pursuing the suggestions he offered. Reflecting on the remarks of Black, Cavalla, about the commencement of the year 1782, made several experiments to elevate a bag filled with hydrogen gas; he tried bladders the thinnest and largest that could be procured; but though cleaned with great care, and every superfluous membrane scraped off, they were found somewhat too heavy for the purpose. He also tried bags of the finest China paper, of such a size, that had it been possible to fill them with the gas, their ascension would have been certain; but the experiments failed, the reason of which was, that though common air would not pass through this paper, hydrogen gas passed through it like water through a sieve. In short, he was completely successful only in filling soap-bubbles with the gas, which was easily done by pressing small quantities of the gas out of a bladder, while a small pipe from the bladder was immersed in a solution of soap and water; these bubbles rapidly ascended in the ambient air, and they may be considered as the first inflammable air-balloons that were ever exhibited.—Cavalla read to the Royal Society the paper in which he gave an account of his experiments, on the 20th of June, 1782.

In the last mentioned year and month, but unknown to the English philosophers, two brothers, Stephen and Joseph Montgolfier, paper manufacturers at Annovay, about 36 miles from Lyons, in France, conceived ideas that led in a short time to the practice of aerostation on a great scale. Taking notice of the ascent of smoke and vapours, it struck them, that if a cloud be enclosed in a bag, a floating vehicle would be immediately formed: their attention was therefore directed to the most feasible method of accomplishing this purpose, or something equivalent to it; and the first experiment was made at

Avignon, by Stephen, the eldest of the two brothers, towards the middle of November, 1782. He prepared a bag of fine silk, in the shape of a parallelopipedon; its capacity was about forty cubic feet, and he applied to its aperture burning paper, which rarified the air, and thus formed in it a kind of cloud; when the bag was in a good degree inflated, he beheld, with high satisfaction, that it ascended rapidly to the ceiling. Encouraged by this success, he subsequently made several experiments in the open air, in conjunction with his brother, and on the fifth of June, before a large assemblage of people, exhibited the powers of a machine of great magnitude. The capacity of the new aerostat was equal to about 23,430 cubic feet, and when inflated it measured 117 English feet in circumference. It was formed of linen, lined with paper; its shape was nearly spherical, and when filled with air, half the density of common air, it was estimated to be capable of lifting about 490 pounds besides its own weight, which, with a wooden frame sixteen feet in surface, that distended the mouth of it, was equal to 500 pounds. It was suspended in a flaccid state on a pole thirty-five feet high; straw and chopped wool were burnt under the opening at the bottom, and the smoke, as it was then chiefly supposed to be which entered it, distended it, in all its parts, and it ascended with such velocity, that in less than ten minutes it reached the elevation of 6000 feet. A breeze carried it in a horizontal direction to the distance of 7668 feet, and it then fell gently to the ground. Balloons of this description were afterwards called *Montgolfiers.*

The brothers supposed that the ascent of their machine was owing to the peculiar nature of a gas disengaged from burning substances, and which was lighter than common air, whereas the real cause was simply the rarefaction superinduced by heat. By the addition of one degree of heat, of Fahrenheit's scale, air expands about one four-hundredth part; and about 435 degrees of heat will just double the bulk of a quantity of air.

The intelligence of the Montgolfiers' experiments no sooner reached Paris, than they engaged the attention of philosophers there, and improvements were immediately suggested. As in the experiments which had hitherto been made, the gas employed was only about one half

the density of common air, it was justly inferred, that inflammable air, which they estimated at an eighth or a tenth part of that of common air, would be still more suitable. They constructed a globular vessel of lutestring, which was rendered more impermeable to the subtile gas, by a varnish of elastic gum. It was thirteen feet in diameter, and had only one aperture like the neck of a bladder, to which a stop-cock was adapted. When it went up it was thirty-five pounds lighter than the same bulk of common air. This machine, from its shape, was called a balloon. On the 27th of August, 1783, it was carried to the Champs de Mars, and in two minutes from the time of its being disengaged from the cords, it rose to the height of three thousand one hundred and twenty-three feet. After having floated about three-quarters of an hour, it fell in a field about fifteen miles distant from the place of ascent. Its fall was owing to a rent occasioned by the expansion of its contents, under a much diminished atmospheric pressure.

The use of rarified balloons was nevertheless not yet superseded; several brilliant experiments were tried with them, and at last Pilatre de Rozier gave new zest to the admiration they excited, by the intrepid offer of becoming in one of them the first aerial navigator. A splendid machine was constructed for this purpose by the younger Montgolfier, who was then in Paris. It was of an oval figure; its diameter was forty-eight feet, and its height about seventy-four feet. To the aperture at the bottom was attached a wicker gallery about three feet broad, with a balustrade about three feet high. An iron grate in which a fire was lighted for inflating the machine, was suspended under the middle of the aperture, by chains which came down from its sides, and port-holes were opened in the gallery, towards the aperture, through which any person who might venture to ascend could feed the fire on the grate with fuel, and regulate at pleasure the dilation of the air enclosed in the machine. The weight of this aerostat was upwards of one thousand six hundred pounds. On the 15th of October, from the midst of an immense multitude, Rozier ascended in this balloon, to the height of eighty-four feet from the ground, where he kept the machine afloat by repeatedly throwing straw and wool upon the fire. The farther

ascension of the machine was prevented by ropes. By a proper management of the fire, Rosier allowed himself to descend gradually, and on regaining the earth, assured the spectators that he had not experienced the slightest inconvenience in his excursion. He afterwards repeated the experiment several times, in one of which, accompanied by Giraud de Villette, he hovered over Paris about nine minutes, at the height of three hundred and thirty feet.—In all these experiments the balloon was secured by ropes, but it was now determined to attempt an unrestricted excursion. Accordingly the same balloon was removed to La Muette, a royal palace in the Bois de Boulogne; and on the 21st of November, Rozier and the Marquis de Arlandes ascended about fifty-four minutes after one. Having reached the height of about two hundred and eighty feet, at an easy and majestic rate of ascent, they waved their hats, as a token of their satisfaction and safety, to the gazing multitude below, and soon after rose too high to be distinguished; but are thought to have attained the height of not less than 3000 feet. When they concluded to descend, they desisted from supplying the fire with fuel, in consequence of which they descended in a field about nine thousand yards from the place of ascent, after having been in the air about twenty-five minutes.

The enthusiasm of acrostatic experiments rose to a great height, and the Parisian philosophers, supported by adequate supscriptions, determined to attempt an aerial voyage with an inflammable air balloon. Charles and Robert were appointed to construct this balloon, and they were the first adventurers in it. It was of a spherical form, and measured twenty seven feet and a half in diameter. The upper hemisphere was covered by a net, which was fastened to a hoop encircling its middle, and called its equator. From this equator proceeded ropes by which was suspended a car in the form of a boat, a few feet below the balloon. In order to prevent the bursting of the machine, by the expansion of the gas in an elevated region, a valve opening inwards was made in the upper part of it; a string descended from this valve into the car, and by pulling at it, the gas might be let out: the car was ballasted with sand-bags. On the 1st of December, 1783, the two aeronauts ascended in this

balloon from the garden of the Tuilleries, in the sight of a prodigious concourse of people. Having with a moderately accelerated velocity attained the height of six hundred yards, they made signals of their safety. They descended in a field about twenty seven miles from Paris, at a quarter past three o'clock, after having travelled at the rate of fifteen miles an hour, yet they did not experience the slightest inconvenience. The balloon still containing a considerable quantity of gas, Charles reascended alone, and in ten minutes he estimated his elevation at nine hundred and fifty nine and three quarters English feet. The pressure of the atmosphere being here greatly diminished, the balloon swelled considerably; he therefore let out some of the inflammable air, after which, as the balloon's power of ascension was increased by the expansion of the gas, in a greater degree than it was diminished by the loss, he rose to a greater height: and it was calculated that he had ascended to the height of nine thousand seven hundred and forty-five English feet. He continued in the air about thirty-three minutes, and by occasionally pulling the string of the valve at the top, to let out the gas, he descended about three miles from the place of ascent. The only inconvenience he had experienced, was from a dry sharp cold, and from a pain in one of his ears and a part of his face, which he ascribed to the extension of the internal air.

In January, 1784, Joseph Montgolfier constructed the largest balloon ever witnessed, and with six other persons, among whom was Rozier, ascended in it. It was 131 feet in height and 104 feet in diameter. It was formed of a double covering of linen, with three layers of paper between, and strengthened with strings and ribbons. It contained about 540,000 cubit feet of rarified air, and its weight including the gallery and passengers, was 1600 pounds. Notwithstanding the care exerted to make this machine strong enough, its descent to the ground was rendered inevitable from the rents it received; one of which was upwards of fifty feet in length. In its descent, when about 600 feet from the ground, its velocity was considerably accelerated; and 60,000 people hastened to the spot full of apprehension, and impatient to know their fate. They were, however, all handed out of the gallery in perfect safety.

The brilliant dawn of a new art which had thus appeared in France, was soon extended to the rest of Europe, and everywhere excited a lively interest and emulation. In London the first public experiment with an inflammable air balloon, was undertaken by Count Zambeccari, an Italian, on the 25th of November, 1783; this balloon was ten feet in diameter; but the first aerial voyage performed in England was by Vincent Lunardi, who ascended from the Artillery Ground, London, on the 15th of September, 1784, with an inflammable air balloon, 33 feet in diameter, made of oiled silk. He started about five minutes after two o'clock, and arrived at Collier's hill, five miles beyond Ware, in Hertfordshire, at twenty five minutes after four.

The spirit of enterprise for these undertakings being now at its height, aerial voyages in various quarters were undertaken in great numbers, and the public journals were continually furnishing new accounts of the adventurers. Even the common people and children caught the enthusiasm of the moment, and at night in London and other parts, little Montgolfiers, made of paper, were often seen traversing the air in the direction of the wind. Many of the great undertakings were in themselves highly worthy of note, but in a collective view they would lose their interest by their resemblance to each other; we shall therefore notice only one or two of the most remarkable. In France, on the 15th of July, 1784, the Duke De Chartres, and the two brothers, Charles and Robert, ascended with an inflammable air balloon from the park of St. Cloud, at 52 minutes past seven in the morning. This balloon was of an oblong form, measuring 55 feet by 34. They remained in the atmosphere about 45 minutes, and descended only a little way from the place of ascension; but the incidents of their voyage are the most singular upon record. The large balloon contained a smaller one filled with common air, the intended use of which was to regulate their ascent and descent without the loss of either inflammable air or ballast. In three minutes they were enveloped in a dense vapour which prevented them from seeing the earth, or being seen therefrom. In a situation thus terrific and sublime they were attacked by a kind of whirlwind, which in a moment turned the machine three times from the right to the

left, and the shocks they suffered entirely prevented them from using the oars and helm they had provided for guiding themselves. Never in their apprehension, did a more dreadful scene present itself to any eye, than that in which they were involved. An unbounded ocean of shapeless clouds rolled beneath, and seemed to forbid their return to the earth, which was still invisible, and the agitation of the balloon became greater every moment. They cut the cords that held the interior balloon, which consequently fell on the bottom of the external balloon, just over the aperture of the tube that went down to the boat and stopped up that communication. A gust of wind from below drove the balloon upwards, to the extremity of the vapour, where the appearance of the sun shewed them the existence of nature: but they were now assailed by other fears; for the heat of the sun and the diminished pressure of the atmosphere, caused so great a dilatation of the gas in the balloon, that they expected it to burst. They introduced a stick through the tube to remove the inner balloon which covered its upper orifice, but the pressure of the dilated gas upon this balloon was so great as to render this impossible. They therefore continued to ascend to the height of about 5100 feet above the surface of the earth, and their danger became greater. In this extremity, to prevent their total destruction by the bursting of the ballon, their only hope was, that a gash cut in it would not spread so far as to be dangerous by letting out the gas too rapidly. Accordingly, the Duke himself, in his earnestness to secure his object, made two holes in the balloon, with one of the spears of the banners. These holes instantly became a rent of seven or eight feet. They now descended rapidly, and as soon as they came in sight of the terraqueous globe, they perceived themselves to be descending into a lake; but the celerity with which they threw out about 60 pounds weight of ballast, a little protracted their flight, and caused them to descend about thirty feet beyond the edge of the water. They were none of them injured.

Among the number of those whom curiosity or the hope of gain by the exhibition induced to become aeronauts, Jean Pierre Blanchard, a Frenchman, much distinguished himself. This person had long been desirous of flying, but previous to the discovery of balloons, his ex-

periments had been directed to the invention of mechanical contrivances for that purpose. The new principles therefore proved exceedingly gratifying to him; and having constructed an inflammable air balloon, 27 feet in diameter, he in a short space of time performed five voyages of the ordinary description. Having thus become a veteran in the service, he determined upon an enterprise, which, at the time it was undertaken, appeared to be one of the most daring that the mind of man could conceive; this enterprise was to cross the channel between Dover and Calais. The balloon he used was the same that he had always hitherto employed. Dr. Jefferies, an American, accompanied him. About one o'clock on the 7th of January, 1785, with a gentle wind about N.N.W. they rose from the cliff before Dover Castle. The day was remarkably fine, and Dr. Jefferies described with rapture the prospect they enjoyed. On one side appeared the formidable breakers on the Goodwin Sands; on the other, in the country at the back of Dover, they counted thirty-seven towns and villages. At 50 minutes past one they found themselves descending, in consequence of which they threw out half their ballast, which at first consisted of three bags of sand weighing ten pounds each. They had now lost sight of Dover Castle, and had accomplished about one third of their journey. Finding, by the rising of the mercury, that they were descending again, they threw out the remainder of their ballast and a part of their books into the sea. At twenty-five minutes after two, they had passed over three-fourths of the channel, and were solaced by an enchanting view of the French coast. Still they were in some danger, for their balloon descended; they therefore threw out the refreshments they had provided, also the oars, or wings of the boat and other articles. "We threw away," says Dr. Jefferies, "our only bottle, which in its descent, cast out a steam like smoke, with a rushing noise; and when it struck the water, we heard and felt the shock very perceptibly on our car and balloon." The descent of their balloon still alarmed them, and they began to throw away their clothes. As a last resource, they were going to fasten themselves to the cords and cut away their car, but at this critical juncture, while yet four miles from the French shore, they perceived themselves to be rising. In

a short time they were greeted by a magnificent prospect, including Calais and twenty other towns and villages. At three o'clock they passed over the high grounds about midway between Cape Blanc and Calais, and descended at last in the forest of Guinnes. None of Blanchard's excursions, amounting to between thirty and forty, remunerated him so well as this. The king of France presented him with a purse of 12,000 livres, and assigned him a pension of 1200 livres a year.

Among the aeronauts of a later date, Sadler, of Oxford, was the most distinguished; he had been in the habit of taking occasional aerial excursions for upwards of twenty-eight years, in balloons constructed by himself; and with the record of his latest excursion we shall close this view of the practice of aerostation. Saddler had for some time, in the early part of 1812, declared his resolution to attempt to cross the channel from Ireland to England; and accordingly, this astonishing act of intrepidity was performed early in October of that year. The bold adventurer ascended from Belvidere Grounds, Dublin, about one o'clock, with a moderate wind at south-west, and in a gradual and majestic style left the shores of Ireland, amidst the blessings, the prayers, and the plaudits of an immense throng, expressed on all sides with the eloquence and energy characteristic of the people of that country. For some time the wind favoured him, but afterwards began to vary, and he hovered about, having the Isle of Man, the Isle of Anglesea, and Ireland, all in view. He was then carried in a direction towards Liverpool, and about half-past four had a distinct view of Bidston light-house, about four miles from that port, which he then confidently expected to reach in about half an hour. By the changing of the wind, however, he was carried completely out of sight of land, and now finding night coming on, and that he must spend it in the air, unless he could avail himself of the assistance of some vessel, he descended to the surface of the water within sight of five sail, but as they took no notice of him he re-ascended; and after a considerable time came down again upon seeing three others. He was now perceived, but encountered considerable difficulty, and was almost drowned by the dragging of the balloon, before he could be got on board a Manx fishing boat, which took

him up in the dusk of the evening. At eight o'clock next morning, he was put on board, and kindly entertained by the commander of the Princess frigate, lying in the river Mersey, opposite Liverpool, at which place he landed, in order to take his seat in the Holyhead mail on his return to Dublin.

Since Sadler, Green has been the most successful aeronaut, and has made several aerial excursions, but none of them worthy of particular notice.

No discovery has ever been made which drew after it a more general admiration, or excited more extravagant hopes of utility to man, than the art of aerostation. It was no sooner announced than already, in the imagination of many, countries were connected and commercial intercourse maintained, with unheard of advantage, while philosophy was to receive vast treasures of new facts to extend her borders. How few of these great expectations, after a lapse of three quarters of a century have been realized; and how little has been added to the real knowledge or conveniences of life, will be discovered from a review of the most interesting facts that the various voyages which have been performed have brought to light.

Of the various circumstances observed by aeronauts during their voyages, when the apprehension of their safety has ceased, none impresses them so strongly than the stillness that reigns around; with some few exceptions, they hear no wind, whatever may be its violence; nor perceive their motion whatever may be its rapidity. To account for this, it must be considered, that the air is, with repect to them, at rest, for they move at the same rate with it. It is also remarkable that they never experience any sickness or giddiness. In one instance, the aeronaut, after his descent, was affected with a temporary deafness, but the wet and cold which he had experienced, would probably have the same effect upon him in a terrestrial journey. Difficulty of respiration, has never been an object of notice. It should not be omitted, that voyages have been performed in all weathers, and at all seasons of the year, and that lightning, which had been dreaded as a potent enemy, has never interposed; upon the whole, it appears probable, that a voyage in a balloon is not more likely to endanger the safety

of an individual, than a voyage from England to Ireland on the sea.

The longest aeronaut excursion ever taken was 300 miles. The greatest height ever attained 13,000 feet.

But slender additions have been made to science from the observations of aeronauts, sometimes because they have not been furnished with proper instruments, but generally because the individuals were incompetent, and had not philosophy, but pecuniary interest in view. It has been found that the air at great heights is rather purer than at the surface of the earth. It has also been observed, that there are often different currents of wind over the place; so that the aeronaut in ascending, goes in one direction till he has attained a certain height, when he is driven in another, and probably in a third: hence, whence he ascends he has no certainty of the direction he must submit to.

The ascending power of a balloon is equal to the weight by which it is lighter than an equal bulk of common air. Every cubic foot of the inflammable air may be considered equal to three and one-sixth drams avoirdupois, which is about one-sixth of the weight of common air. Hence, if the capacity of a balloon be such, that it contains 12,000 cubic feet of this gas, its ascending power may be estimated at 12,000 ounces; and, therefore, the aeronaut, with the boat and all other appendages, must weigh less than this. An inflammable air balloon, if twenty feet in diameter, will just suffice for one person.

In a rarefied air balloon, or Montgolfier, the air cannot be expected to be above one-third lighter than air, and a machine of this sort, must, therefore, be in that proportion larger than the other, to have an equal ascending power.

To witness the flight of a large balloon, has an effect upon the mind, as different to describe as it is impossible not to feel. So spacious a globe, with the magnificence of the decorations, excite admiration; the apparently precarious situation of the adventurers raises apprehension; a machine of such extraordinary dimensions majestically making its way through a medium which is incapable of supporting a feather;—impressions from all these sources combine to form a mingled sentiment of

the deepest interest, unlike that produced by any other exhibitions of art. Many have not been able to bear the spectacle without shedding tears; others have involuntarily lifted their suppliant hands to heaven, or fallen upon their knees; several have fainted, and at Lunardi's first ascent, a delicate female was so overcome by her feelings, that she died upon the spot.

CONSTRUCTION OF BALLOONS.

There are, as already mentioned, two kinds of balloons, viz., those filled with rarefied air, and those filled with inflammable air.

The best form of balloons, of both kinds, is that of a globe, the capacity of which figure, is, for its surface, greater than that of any other. Next to a globe, an elliptical or egg-shape should be preferred; for these forms the longer axis should be horizontal, because that is the direction in which they would naturally float, in order that their centres of gravity may be the lowest possible.

The envelope of large rarefied air balloons is generally made of strong linen, lined within and without with paper, over which is laid a varnish consisting generally of strongly dried linseed oil. As a precautionary measure against fire, it is usual in the first instance, to prepare the linen, by soaking it in some fluid that will render it less combustible, for example a solution of alum, or of sal ammoniac and size, using one pound of each to every gallon of water; and when the cloth is dry to paint it over with some earthy colour, and strong size or glue.

Small rarefied air balloons are made of paper which has not undergone any new preparation whatever. The paper must be of that kind called tissue, and chosen free from the small holes which are often in it; the pieces are united together by means of flour-paste or gum-water, till a globular bag is formed. A single aperture is then made in it, about ten or twelve inches in diameter, to which is fastened a ring of slender wire, and fastened to

each side of it, passes a strong wire, upon the middle of which is hung a ball of spun yarn, or a spunge dipped in spirits of turpentine. When the spirits are lighted, the balloon inflates by the expansion of the air within it, and when it is at its full size, it is suffered to take its flight.

No kind of stuff has been so suitable for inflammable air balloons as silk, particularly that kind called lute-string. The silk should be woven on purpose, and at the distance of each eighteen inches both in the warp and woof, should be inserted a strong cord of flax or silk, so as to form squares in the web. By taking this precaution, when a rent is made in the balloon, the length of it will not extend beyond the square in which it commences. To the upper part of the balloon should be adapted a valve opening inwards, to which should be fastened a string passing through a hole made in a small piece of wood, which is fixed in the lower part of the balloon. The string reaches into the car, so that the aeronaut may at any time open the valve with facility. Those parts of the valve and its frame, which are in contact, are covered with thick, soft leather, and the valve is kept close by a spring. To the lower part of the balloon, and opening into it, are affixed two pipes, of the same kind of stuff as the envelope. Through these pipes the balloon is filled, and for a balloon of thirty feet, they should be about six inches in diameter.

The car or boat of a balloon, for the reception of the aeronaut, should be made of wicker-work, and covered with leather well painted or varnished. The balloon is covered with a net, made to its shape, and to this net are fastened the ropes which support whatever it is intended to carry up. The net is generally made large enough to cover the greater part of the balloon, though sometimes it covers only half of it; the various cords from it proceed to the circumference of a circle or ring to which they are fastened. From this ring, which is composed of slender pieces of cane bound together, proceed the ropes by which the boat is suspended, at the distance of several feet below the balloon. For the sake of greater strength, the meshes of the net are made closest at the top, where there is the greatest strain, and very gradually larger lower down.

To stop the dragging of a balloon after it has descended

almost to the earth, the aeronaut is provided with two small anchors, or grappling irons, which are shaped either like a ship's anchor or like three fish hooks, tied together. These are thrown out so as to catch hold of trees or other fixed objects.

MAGNETISM.

A PECULIAR species of attraction, exerted by bodies called magnets or loadstones, receives the appellation of *magnetism*.

Of magnets there are two kinds viz., the natural and the artificial. The natural magnet is a mineral, so hard as to strike fire with steel; its colour is dull, and generally either dark grey, or brown, or nearly black. It is an ore of iron, and derives its name of magnet, from its possessing the singular property of attracting ferruginous substances, with a force entirely independent of the ordinary properties of matter. This power of attraction may be communicated to iron in any state, under a variety of circumstances; and iron imbued with it in any considerable degree, is called an *artificial magnet* or *loadstone*. Magnetism is an accidental property of iron, which may either possess or be deprived of it without losing any of its essential characteristics.

Magnetic attraction was till lately supposed to be exerted by ferruginous bodies alone on other ferruginous bodies, and hence the use of the magnet was resorted to, with a view to detect the presence of iron; but modern investigations render it probable that nikel is also susceptible of it. Richter, having made a series of experiments on this metal, considers it more attractable by the loadstone than iron; and Chenwix is of opinion that both nikel and cobalt are really magnetic, and that when this does not appear to be the case, it is owing to their combination with arsenic.

A magnet suspended by a thread, or placed in any situation that leaves it at liberty to move with freedom,

turns one part of its surface towards the north pole of the earth, and, consequently, the opposite part of its surface towards the south pole. Those parts of the surface of a magnet which assume the position stated, are called its *poles;* they are not reversible points, but the pole which is at any time observed to point towards the north, always points in the same direction or nearly so, and the like remark must, of course, apply to the other or south pole.

The attractive properties of the magnet have been known from time immemorial; but it was not till about the close of the twelfth or beginning of the thirteenth century that its directive property became known. The discovery of it is generally attributed to John de Gioja, a handicraft of Naples, although several authors previous to his time had obscurely intimated their knowledge of it. Gioja having observed the property by accident in a few magnets, soon extended his researches, and found that it was common to them all, at least at the place where he lived. Sensible of the value of the acquisition the world would obtain if the property he had thus discovered remained unimpaired by time or place, he made several journeys to various parts of Italy, to prove its immutability, and his inquiries satisfied him that there was no perceptible difference in it, except by the vicinity of masses of iron. The first trial of the directive property of the magnet on the water consisted in mooring a vessel out at sea in a direction corresponding with that of the magnet; and a boat, having a magnet suspended by its centre on a pivot, was despatched at night in the exact line the magnet pointed out, the consequence of which was, that it arrived at the place where the vessel was at anchor. Such was the origin of the mariner's compass, the inestimable value of which as a guide in crossing the ocean, and trackless deserts, as well as in other circumstances of minor importance, can be more duly appreciated by the supposition of our situation under the want of it than by any other means.

The magnetic needle does not, in general, rest exactly in the direction of the meridian of the place where it is observed, consequently not directly north and south. This phenomenon, which is called the *Declination of the Magnet,* was discovered in the year 1500; but the son of

Columbus asserts, that his father observed it in 1492. At first it was not doubted, that the magnetic declination was an equal quantity at all times and places; but Gellibrand, an Englishman, discovered that it was variable, and published an account of this discovery in a pamphlet printed in 1635.

Another property of the magnetic needle, much more singular than that of the declination is, that when suspended by the point which would be its centre of gravity according to its mass of matter, it does not remain horizontal, but one extremity sinks lower than the other. This is called the *dipping* of the needle or magnet, and it varies in different latitudes. In the southern hemisphere, it is the south pole which is depressed; and in the northern hemisphere it is the north pole. At the equator, the needle assumes a position almost correctly horizontal. The dipping of the needle was discovered by R. Norman, who published his account of it in 1581, but he had ascertained the fact a considerable time previously.

If the north pole of one magnet be presented to the south pole of another, the two magnets will attract each other; but if the north pole of one be presented to the north pole of the other, they will repel each other, provided they be suspended by thread, or in any other way at liberty to move with perfect freedom. This is called *Magnetic Repulsion.*

Magnetic repulsion never takes place except between poles of the same name; thus a north pole repels a north pole; and a south pole repels a south pole; yet, when the north pole of a weak magnet is presented to the north pole of a powerful one, an attraction is often observed; but when this occurs, it is found that the poles of the weaker magnet have been in reality reversed, and its north pole has acquired polarity.

THEORY OF MAGNETISM.

The only proposition towards the Theory of Magnetism which seems placed beyond the reach of doubt, is, that the earth itself acts as a great magnet; and if this be evident, it will scarcely be denied, that all other magnets derive their power and properties from its effects. Supposing the earth to be a magnet, the manner in which it operates, in causing the directive property and inclination, or dipping of the needle, is just what might be expected, and may be exemplified by an easy experiment: over the needle of a magnet, hold a magnetised needle, suspended by a fine thread, and so fixed, that if it were removed to a distance from any magnet or iron, it would remain horizontal. In this position, the needle, being equally attracted by both ends of the magnet, remains horizontal, but it turns its north pole to the south pole of the magnet, and its south pole to the north pole of the magnet. A globular magnet exhibits this epitome of magnetism in a still more agreeable manner, and a magnet of that kind made for the purpose is called a terrella, or little earth. As the large magnet in this experiment acts upon the needle; so does the earth upon all other magnets. When the centre of the needle in this experiment, is over the centre of the magnet, it corresponds nearly to the situation of any suspended magnet at the equator of the earth, where the attraction from both poles is nearly equal; and where the needle would be exactly horizontal, if the magnetical and geographical poles of the earth coincided; but, as this is not the case, the magnetical and geographical equators are differently situated.

That the earth is a magnet also admits of strong collateral proofs; it may be inferred from the vast quantities of ferruginous bodies contained in it, which are often dug up in a magnetical state, and from the magnetism which iron acquires by its position. Yet all this carries us but a very little way towards a complete theory of magnetism. For example, it is found, that the magnetical

poles of the earth change their situation, and this singular circumstance has opened a wide field for speculation. It has been supposed that the earth contains a detached internal magnet, which has a different motion from that of the earth, though both their axis coincide. This internal loadstone is supposed to be separated from the outer globe or earth by a fluid medium; and to account for the variation of the needle westward, they suppose its motion with respect to that of the earth, to be such, that its north pole revolves from east to west, at the rate of one degree in five years, so as to make a complete revolution in 1920 years. This theory has never given much satisfaction; and it seems much more rational to conclude, that the magnetism of the earth arises from the magnetism of all the magnetic substances it contains, whether intermixed with other bodies or not; that the magnetic poles of the earth may be considered as the centres of the polarities of all the particular aggregates of the magnetic substances within the earth, are by various causes altered, so as to have their power diminished, increased, approach to, or removal from the principal poles The agents adequate to the production of these effects may be, heat and cold, volcanoes, earthquakes, electricity, chemical decompositions, and probably several others, of which philosophers have no knowledge.

By those who had so far deserted the paths of morality, as greedily to fatten upon the weaknesses of their fellow creatures, and boldly to venture upon any practice, however really flagitious, if it promised gain, and was screened from legal punishment; a pretended art called animal magnetism, was impudently announced as curative of all diseases incident to the human body. The vulgar, who are always perversely fond of a mysterious creed, seized the bait, and the pockets of the projectors overflowed with the receipts of their impositions. When the folly of the moment had passed away, and the subject was rationally examined, abundant evidence was furnished, that though the human body contained, like most other substances, a small quantity of iron, the action of magnetism produced no physical change upon it, and that, therefore, the cures said to have been performed by magnetic sympathy, were either absolute falsehoods, or mere efforts of a deluded imagination. After animal

magnetism appeared to have had its day, and was sinking fast into disrepute, it was succeeded by a kindred invention, the wonders of which were performed by rods of metal called *metallic tractors;* but these quickly followed their parent to the grave.

MAGNETICAL INSTRUMENTS.

The *Mariner's Compass.*—The chief magnetical instrument is the mariner's compass, which consists of a circular brass box, containing a card or paper divided into thirty-two points, at each of which is given the name of a particular wind, or name of the direction to which it points. Over the centre of this card is suspended an artificial magnet, which, from the smallness of its size is called a needle. As the needle, allowing for its declination, always turns its north pole to the north, the helmsman can either keep the stem of the vessel always in the same direction, in which case he will always sail due north, or he can keep it in a direction any number of degrees distant from the north at his pleasure, by which means the compass becomes a universal guide.

In steering a vessel, it has been usual for the helmsman to have one compass, and the captain in his cabin to have another, and the want of a perfect correspondence between the instruments, or the inattention of one party, often rendered the helmsman chargeable with neglects, which he refused to acknowledge. To remedy such inconveniences, an improvement on the compass was made, by which the instrument used by the helmsman could at all times be seen from the cabin.

The *Azimuth Compass.*—This instrument is nearly the same as the preceding: the principal difference consists in its being adapted to two sights, through which the sun or a star may be seen, to find its azimuth, and thence to ascertain the declination of the needle at the place of observation.

The *Dipping Needle.*—To form this instrument, an axis is passed through a needle, of the same shape as the com-

pass needle; the terminations of the axis are conical, and they fit into small holes of the same shape in two cross bars. The needle before it is magnetized, must be made so as to lie perfectly horizontal when suspended between those bars; then after being rendered magnetic, its north pole will be found in this country to dip about 72 degrees below its former situation, or level of the horizon. In a lower latitude the dip will not be so great; in a higher latitude it will be greater; and at the magnetic pole, which cannot be far removed from the pole of the earth, it would doubtless be vertical.

MAGNETICAL EXPERIMENTS.

1. If a small magnet be placed upon a table strewn with iron filings, and a tremulous motion be given to the table by a few blows, the filings will be observed to arrange themselves in a very curious manner. From the centre of each hand or pole of the magnet, they will lie nearly in a straight line; but on each side of the magnet they will dispose themselves in concentric curves, both extremities of which terminate in the sides of the magnet, and they have pretty nearly the magnetic centre for their middle point. The cause of this appearance is, that each particle of iron becomes, for the moment, a magnet, and disposes itself accordingly at the place where it lies; attracting, at the same time, the opposite poles of the neighbouring particles.

2. If a straight piece of wire which has been rendered magnetical, be twisted in a spiral form, its magnetism will be strangely confused: in some parts it will attract, in others repel the same pole; and this will, in some portions of the wire, take place on its opposite sides. This experiment appears to indicate the disposition of the fluid to flow in a right line.

3. A tee-totum with a piece of iron in the top of it may, even while in motion, be taken up by a magnet, and its motion, while thus suspended vertically, will continue as if it remained upon the table. The experiment may be

rendered still more diverting, by taking up another teetotum by the bottom of the first, and this second may have its motion in a completely opposite direction to the other.

ELECTRO-MAGNETISM.

The analogies that exist between the phenomena of magnetism and those of electricity, in their general character, in the laws which govern them, and in the various combinations they present, are so extensive and so remarkable, as naturally to suggest the notion that the agencies themselves from which they proceed must be allied to one another by some close and intimate relation. Adventurous theorists have advanced the doctrine that each of these principles is merely a modification of the other, and that both may be regarded as ultimately identical in their nature, constituting instead of two separate and primary powers a single power of a higher order of simplicity.

The connexion between magnetism and electricity was a favourite subject of speculation and inquiry among philosophers in the middle of the last century. Many were the efforts made to resolve this seductive problem, which continued, however, to baffle the labours of each succeeding experimentalist, who multiplied his attempts, and varied his processes, without approaching nearer to the point he aimed at; and also to elude the reasonings of those who theorized upon every new fact until they bewildered both themselves and their readers in the mazes of visionary and conflicting hypotheses.

In the year 1774, the following question was proposed by the Electoral Academy of Bavaria as the subject of a prize dissertation.—"Is there a real and physical analogy between electric and magnetic forces; and, if such analogy exist, in what manner do these forces act upon the animal body?" The essays received by the Academy on that occasion, were collected and published ten years afterwards, by Professor Van Swinden, of Franeker, the

author of one of the essays for which the prize was awarded. The conclusion at which he arrived, after a long and elaborate discussion of the subject, was that the similarity between electricity and magnetism amounts merely to an apparent resemblance, and does not constitute a true physical analogy; whence he infers, that these two powers are essentially different and distinct from one another. The opposite opinion, on the other hand, was maintained by Professors Steiglehner and Hubner, who contended that so close an analogy as that exhibited by these two classes of phenomena, indicated the effects of a single agent, varied only in consequence of a diversity of circumstances. So many new facts have been brought to light since the time in which these authors wrote, that the reasonings adduced on either side in this controversy have now lost their interest, excepting that it is still curious to observe by what devious paths they were led away from the truth, at the moment when they had nearly reached it, and when a very slight variation in the form of their experiments would at once have disclosed it to their view.

Subsequent discoveries relating to the laws of electric and magnetic action both as respects attraction and repulsion, and also induction, have tended to confirm the analogy between them, and to corroborate the opinion that they ultimately emanate from a common source. Electricity, it is true, affects every species of matter with which we are acquainted, in nearly an equal degree; while magnetism, although perhaps equally universal in its operation, yet acts very feebly, and, probably, unequally upon most kinds of matter, and certainly exerts its principal energy upon iron, a circumstance which has to this day remained inexplicable; although we have acquired the knowledge that electricity, under certain modifications, will produce every effect of magnetism. Electricity, we know, may be transferred from one body to another; but magnetism can be excited by induction only, and is incapable of any similar kind of transference. Still, however, there existed many positive facts, which, independently of all analagy, demonstrated that the magnetic needle was occasionally influenced in its movements by the action of electricity; and that, in certain cases, the magnetic properties could be excited by electric ex-

plosions. The appearance of the aurora borealis, which has all the characters of an electric phenomenon, has been very frequently observed to be accompanied by a disturbance in the position of the compass; and a delicately suspended magnetic needle has generally exhibited on these occasions, very frequent oscillations. Lightning, which is still more decidedly electric has been known in numberless instances, to destroy, and sometimes to reverse the polarity of the compass-needle; and many disastrous accidents happening to ships, in consequence of their mistaking their course, may very probably have been owing to this cause. In confirmation of this, we meet with a narrative recorded in the Philosophical Transactions, in which the ship Alexander, being one hundred leagues from Cape Cod, in latitude 48 degrees, encountered a violent thunder-storm; the mast was struck by lightning, which also reversed the poles of all the compasses in the ship, a change which was not discovered till the ensuing night, when the stars appeared, and it was found that they had been steering in the opposite course to that which they intended. It is also stated, that in one of the compasses, the end which had before pointed to the north now pointed to the west. Another instance is recorded in the same work, where a stroke of lightning passed through a box containing a great number of knives and forks, melting some, and scattering the rest about the room. It was found that all those which were not melted had been rendered strongly magnetic, so as to take up large nails, and other pieces of iron placed near them.

Experiments were tried with the electric battery, in imitation of these effects, and in order to ascertain the circumstances on which they depended. But although steel bars were easily rendered magnetic by passing strong electric shocks through them, yet the results were by no means uniform, and no general law could be traced as governing the production and distribution of the polarity thus induced. A large proportion of the effects appeared to be referable to the concussion which the particles of the bar received in consequence of the violence with which the accumulated torrent of electricity rushed through them, thereby giving efficacy to the inductive influence of the earth. The experiments of Mr. Scoresby, as reported in the Transactions of the Royal Society of Edin-

burgh, made with a view of determining the amount of this influence when aided by electric concussion, fully confirmed the principle upon which that mode of explaining the phenomenon rests, by showing that the action of a powerful electric shock is, in a great measure, similar to that of a blow from a hammer, or to the forcible twisting of the iron, or any kind of mechanical violence.

Nothing illustrates more forcibly the proneness of the human mind to draw general conclusions from insufficient data, than the various opinions so confidently maintained by different experimentalists on this subject.

As nothing had been gained by following the more violent operations of highly-condensed charges of electricity, other philosophers occupied themselves in the attentive study of the more tranquil influence of this agent, when merely accumulated in insulated conductors, and exerting simply its attractive and repulsive powers in conjunction with those of magnetism. But however the actions might be combined, nothing could be detected that indicated any interference of agency or modification of effect consequent on the combination. An electrified body is found to exert the same attractions and repulsions on a magnetized needle, as it does on the same needle when devoid of magnetism; nor does it, like magnetism, exhibit any decided preference for iron compared with its action on other metals. When the two agencies are united in the same body, or when bars of steel, already rendered magnetic, are also charged with electricity, and placed so as to act with one another, their electrical and their magnetic actions appear to be perfectly distinct, and in no respect to influence or modify one another.

The discovery of Galvanism, and the invention of the Voltaic apparatus, opened a new field of inquiry; for by furnishing the experimentalist with the means of maintaining a continuous current of electricity in very large quantity, it enabled him to study the effects of this powerful agent under circumstances of a very different kind from those he had previously had under his command.—The electro-chemical phenomena, brought to light by its application to another branch of physical science, for a long time occupied the talents and absorbed the attention of scientific men in every part of Europe, and many years elapsed before Voltaic electricity was applied with

any success to determine the influence which it so directly exerts over magnetic bodies. The various hints interspersed among the journals of this period, respecting movements having been observed in the magnetic needle by the action of the Voltaic pile, were too vague and uncertain to warrant any determinate conclusion. The most definite and authentic narrative relating to this subject was that of Ritter, who asserted that a needle, composed of silver and zinc, had arranged itself in the magnetic meridian, and had been slightly attracted and repelled by the poles of a magnet. He also stated, that by placing a gold coin in the Voltaic circuit, he had succeeded in giving to it positive and negative poles; and that the polarity so communicated was retained by the gold after it had been in contact with other metals, and appeared, therefore, to partake of the nature of magnetism. A gold needle, placed in similar circumstances, acquired still more decided magnetic properties. These experiments suggested to Ritter some vague idea that electrical combinations, when not exhibiting their electric tension, were in a magnetic state; and that there existed a kind of electro-magnetic meridian, depending on the electricity of the earth, at right angles to the magnetic poles. But these speculations were of too crude a nature to throw any distinct light on the true connection between magnetism and electricity.

The real discoverer of the magnetic properties of electric currents was M. Oersted, Professor of Natural Philosophy, and Secretary of the Royal Society of Copenhagen. In a work which he published about the year 1813, on the identity of chemical and electrical forces, he had thrown out conjectures concerning the relations subsisting between the electric, galvanic, and magnetic fluids, which he conceived might differ from one another only in their respective degrees of tension. If galvanism, he argued, be merely a more latent form of electricity, so magnetism may possibly be nothing more than electricty in a still more latent form; and he therefore proposed it as a subject, worthy of enquiry, whether electricity, employed in this, its most latent form, might not be found to have a sensible effect upon a magnet. It is difficult clearly to understand what he means by the expression *of latent form*, as applied to electricity, but it is sufficient

for us to know that in the various endeavours he subsequently made to verify his conjectures, he was led to such forms of experiment as afforded decisive indications of the influence of Voltaic currents on the magnetized needle. Yet even after he had succeeded thus far it was a matter of real difficulty to determine the real direction of this action, and it was not till six years afterwards that his perseverance was at length rewarded by complete success.

The first account of his discovery that appeared in England, is contained in a paper which he himself communicated, in Thomson's Annals of Philosophy, for October, 1820; and in which the two following experiments is described.—The two poles of a powerful Voltaic battery were connected by a metallic wire so as to complete the galvanic circuit. The wire which performs this office is called the *uniting wire*; and the effect, whatever it may be which takes place in this conductor, and in the space surrounding it, during the passage of the electricity, he designates by the term *electric conflict*, from an idea that there takes place some continued collision and neutralization of the two species of electric fluids, while circulating in opposite currents in the apparatus. Then taking a magnetic needle properly balanced on its point, as in the mariner's compass, and allowing it to assume its natural position in the magnetic meridian, he placed a straight portion of the uniting wire horizontally above the needle, and in a direction parallel to it; and then completed the circuit, so that the electric current passed through the wire. The moment this was done the needle changed its position, its end deviating from the north and south towards the east and west, according to the direction in which the electric current flowed, so that by reversing the direction of the current, the motion of the needle was also reversed. The general he expressed as follows:—"That end of the needle which is situated next to the negative side of the battery, or towards which the current of positive electricity is flowing, immediately moves to the westward.

The deviation of the needle is the same whether the uniting wire, instead of being immediately above the needle, be placed somewhat to the east or west of it, provided it continue parallel to, and always above it.

This shows that the effect is not the result of a simple attractive or repulsive influence, for the same pole of the magnetic needle, which approaches the uniting wire when placed on its east side recedes from it when placed on its west side.

If the uniting wire be placed in a horizontal plane under the magnetic needle the latter is affected to an equal degree as in the former case, but the motions are made in the contrary direction; for the pole of the needle next to the pole of the battery now deviates towards the east.

When the uniting wire is situated in the same horizontal plane as that in which the needle moves, and is at the same time parallel to it, no declination takes place either to the east or west; but the needle is inclined, so that the pole next to the end of the wire at which the negative electricity enters is depressed, when the wire is situated on the west side, and elevated when situated on the east side.

Oersted found that these experiments succeeded equally well if the uniting conductor consisted of one or of several wires, or metallic ribbons, connected together. Neither is the effect altered in its kind, though it may vary somewhat in its degree, when different metals are used. The conductor still exerts this power, although it be interrupted by water, provided the interval between the metals does not extend to several inches in length. The magnetic influence of the wire on the needle is not prevented by the interposition of glass, metals, wood, water, resin, stones, or any other substance that was tried. The effect produced, nevertheless, is referable purely to magnetism, for it is exerted on magnetic bodies only, and has no influence on needles of brass, glass, or gum-lac.

The announcement of the important discovery of Oersted excited the greatest interest among all the philosophers of Europe, and they immediately occupied themselves in repeating and extending his experiments. Among those who were early distinguished by their zeal and activity in this research were Ampere and Corago in France, and Sir H. Davy and Faraday, in England. So many were the cultivators in this new field of inquiry, and so eagerly did they pursue the path thus unexpectedly

opened, that a great number of interesting facts were speedily brought to light; and where all were pressing forward in the same career, it is scarcely possible to adjust the claims to priority of discovery, with respect even to the most important facts.

An attentive examination of what has been already stated on this subject will soon convince us that the magnetic force, which emanates from the conducting wire, is entirely different in its mode of operation from all the other forces in nature with which we are acquainted. It does not act in a direction parallel to that of the current which is passing along the wire, nor in any plane passing through that direction. It is evidently exerted in a plane perpendicular to the wire, but still it has no tendency to move the poles of the magnet in a right or radial line, either directly towards or directly from the wire, as in every other case of attractive or repulsive agency. The peculiarity of its action is that it produces motion in a circular direction all round the wire, that is, in a direction at right angles to the radius, or in the direction of the tangent to a circle described round the wire in a plane perpendicular to it. Hence, as Mr. Barlow expressed it, the electro-magnetic force exerts a *tangential action*.

When the direction of the current is reversed, the wire still preserving its vertical position, the direction of the section is also reversed; and the circular motions produced correspond to the movements of the hands of a watch with its face downwards; that is still looking towards the positive electrical pole.

The actions of either the descending or ascending electrical current upon the south pole of a magnet are exactly the reverse of those which are exerted on the north pole. On reversing the direction of the current these effects will again be reversed.

It is evident that in the course of experiments on electro-magnetism, the current and magnetic poles may be presented to our observation in a great variety of relative positions; and it will be found not very easy to retain a perfect recollection of the way in which the force should act conformably to the rule above stated. Ampere has hit upon an ingenious method for imprinting this rule more firmly in the memory, and enable us to apply it under a

great variety of circumstances. The electric currents are not only characterised as positive and negative, and as flowing in one or other of two directions along the wire that conducts them, but may be actually personified and conceived as endowed with a head and feet, with a face and back, and with a right and left hand.

It is more natural to fix our attention on the current of positive than of negative electricity. In a vertical wire, a descending current will occur to us more readily than an ascending one; or if we imagine ourselves borne along by the current, it would be more natural to conceive ourselves moving with our feet foremost; but if on the contrary, we conceive ourselves to be at rest, we should suppose the current to be passing from our head to our feet. Our face would, of course, be turned towards the magnetic pole to which we are directing our attention; we should attend to the north pole in preference to the south; and the movement with which we are most familiar is that which we perform with our right hand, as in writing, for instance, that is from left to right. Combining these conditions then, we may always recollect that if we conceive ourselves lying in the direction of the current, the stream of positive electricity flowing through our head towards our feet, with the magnet before us, the north part of that magnet will be towards our right hand. If any of these conditions be reversed, the result is reversed likewise.

The direction of the electro-magnetic force being thus determined, we have next to ascertain the exact law, according to which its intensity varies with relation to the distance of the electric current from the point in which it acts. The most reasonable conjecture we can form on this subject is, that this law is the same with that which is followed in the case of electric and magnetic actions, that the intensity of force is every where inversely as the square of the distance. But if this be the real law of action, it must apply to the elementary portions of the two agents which thus mutually act upon each other; or, to adopt the more convenient language of theory, it must obtain only among the elementary particles of the electric and magnetic particles of the electric and magnetic fluids. In the magnet, the action of the latter may be regarded as concentrated in the points,

which are the poles of the magnet; but in the conducting wire, the electric fluid which is passing through it, acts in an equal degree along the whole line of its motion; and admitting the hypothesis of the action being inversely proportional to the squares of the distances of each individual particle, we have to deduce the law which will result from the combined actions of all the points of a line directed upon a point out of that line. Now, it may be mathematically demonstrated, that if the line in question be perfectly straight, and its length be exceedingly great in proportion to the distance of the point on which it acts, then the intensity of action will be inversely proportional, not to the square, but to the simple distance of the point, so that at three times the distance, for example, the force shall be one-third, and four times the distance, one-fourth, and so on. That this law is conformable to observation, has been proved by many experiments, in which the intensities of the force at different distances were accurately ascertained by observing the number of oscillations performed by the needle in a given time, and taking the squares of those numbers.

The discovery of the remarkable phenomena of electro-magnetism naturally gave rise to the invention of a variety of hypotheses for their explanation. Professor Oersted conceived that a distinct class of effects resulted during the act of their re-union, which was marked, not only by mechanical agitations among the particles of bodies, by the production of sound, by the evolution of light, and by the disengagement of heat, but also by the disturbance of the magnetic equilibrium. These phenomena seemed to indicate the occurrence of great and sudden changes taking place in the conditions of two powerful agents at the moment of their coalescence, and suggested to Oersted the idea that something analogous to a shock takes place when the fluids rush together from a distance. During galvanic action the separation of the two electric fluids, proceeding without intermission in one part of the apparatus, and their reunion being in like manner effected in perpetual sequence along the conducting bodies which complete the circuit, he conceived that a continued series of shocks took place throughout the

whole line of conductors; a condition which he expressed by the term *Electric Conflict.*

If these views be correct, it must follow that the electric fluids, which, whether in motion or at rest, have, when isolated, no apparent influence on magnetic bodies, acquire during their conflict the power of affecting these bodies. This hypothesis was expressed by Oersted in the following words:—"The electric conflict acts only on the magnetic particles of matter. All non-magnetic bodies appear penetrable by the electric conflict, while magnetic bodies, or rather their magnetic particles, resist the passage of this conflict. Hence they can be moved by the impetus of the contending powers. It is sufficiently evident that the electric conflict is not confined to the conductor, but dispersed pretty widely in the circumjacent space.

"We may likewise collect that this conflict performs circles; for without this condition, it seems impossible that one part of the uniting wire, when placed below the magnetic pole, should drive it towards the east, and when placed above it, towards the west: for it is the nature of a circle that the motions in opposite parts should have an opposite direction. Besides, a motion in circles, joined with a progressive-motion, according to the length of the conductor, ought to form a conchoidal or spiral line; but this, unless I am mistaken, contributes nothing to explain the phenomena hitherto observed.

"All the effects of the north are easily understood by supposing that magnetic electricity moves in a spiral line bent towards the right and propels the north pole, but does not act on the south pole. The effects on the south pople are explained in a similar manner, if we ascribe to positive electricity a contrary motion and power of acting on the south pole, but not upon the north."

The views entertained by Oersted were very generally adopted by philosophers who prosecuted the path of discovery he had laid open.

All the effects of terrestrial magnetism may be imitated by distributing wires round the surface of an artificial globe, so as to direct a current of electricity through them. Mr. Barlow, in a paper read at the Royal Society, describes the following experiment, which he made with

this view. A hollow wooden globe, sixteen feet in diameter, was furnished with copper wires passing in grooves along each parallel of latitude for every tenth degree. When an electric current was made to pass through these wires, in the same direction in each, it was found that a magnetic-needle, properly neutralized with regard to the earth's action, and suspended in different situations near the surface of the artificial globe, arranged itself in positions perfectly analogous to those actually assumed by the dipping-needle in corresponding regions of the earth. It is probable that if we could indefinitely multiply these electric currents on a globe so prepared, the apparatus might be made to represent with great accuracy every circumstance of magnetic dip and direction; and by employing, instead of a magnetic needle, an electro-dynamic cylinder, all the phenomena of terrestrial magnetism might be exhibited, without the intervention of magnetism, by means of electricity alone.

Professor Seebeck, of Berlin, discovered in the year 1822, that currents of electricity might be produced by the partial application of heat to a circuit composed exclusively of solid conductors. The original experiment which he established, was first announced in this country in the Annals of Philosophy. A bar of antimony, about eight inches long, and half an inch square, was taken, and its extremities connected by twisting a piece of brass wire round them so as to form a loop, each end of the bar having several coils of the wire. On heating one of the extremities for a short time, with a spirit lamp, electro-magnetic effects were produced in every part of a circuit so formed. The electric current thus excited has been termed *Thermo-electric*, in order to distinguish it from the common galvanic current, which, as it requires the intervention of a fluid element as one of its essential components, was denominated *Hydro-electric current.*

The chief evidence we possess of the existence of thermo-electric currents consists in the production of electro-magnetic effects. A compass-needle either within or without the circuit, and at a small distance from it, is deflected from its natural position in a direction conformable to its situation with regard to the circuit.—Still stronger indications of electro-magnetic action are obtained by placing two ends of one of the metallic

arcs in contact with the wires of a galvanometer. The thermo-electric current has also been found to excite contractions in the muscles of a frog; but as far as experiments have yet been tried, it is inadequate to effect chemical decompositions, the ignition of metals, or to exhibit sparks or any other of the phenomena of ordinary electricity.

INFLUENCE OF LIGHT ON MAGNETISM.

Professor Morichini, of Rome, announced his having discovered that steel, exposed in a particular manner to the concentrated violet rays of the solar spectrum, became magnetic; but the uniform failure of the experiment, when tried by other persons, had created great doubts of the accuracy of the results as reported by Morichini. In the course of some experiments made by Mr. Christie, in the year 1824, he was led to the conclusion that the solar rays actually do exert a sensible influence on magnetism, which is shown by their affecting the vibrations of a magnetic needle exposed to them, quite independently of the effects produced by the heat which they impart. A needle six inches long, contained in a brass compass, but with a glass cover, was suspended by a fine hair, and made to vibrate, alternately shaded and exposed to the sun. He found, from a number of trials, that the vibrations of the needle, when exposed to the sun, ceased in a much shorter time than when they took place in the shade. That this greater slowness of the vibrations was not attributable to a change of temperature, was proved by the needle's being observed to vibrate more rapidly when its temperature was raised by other means.

In the Philosophical Transactions for 1826, we are informed that, in the summer of 1825, Mrs. Somerville was induced, by the unusual clearness of the weather, to investigate the subject. Having at that time no information of the manner in which Morichini's experiments had been conducted, it occurred to her that, if the whole

needle were equally exposed to the violet rays, it was not probable that the same influence which produced a south pole at one end, would, at the same time, produce a north pole at the other. She therefore covered half of a slender sewing needle, an inch long, with paper, and fixed it in such a manner as to expose the uncovered part to the violet rays of a spectrum, thrown, by an equiangular prism of flint glass, on a pannel at five feet distance. As the place of the spectrum shifted by the motion of the sun, the needle was moved so as to keep the exposed part constantly in the violet ray. The sun being very bright, in less than two hours the needle, which before the experiment showed no signs of polarity, had become magnetic, the exposed end having the properties of a north pole.

The season continuing favourable, afforded daily opportunities of repeating and varying the experiments with needles of different sizes and placed in different positions with respect to the meridian, and at different distances from the prism. The result was nearly uniform, and similar to that above stated. It was not found necessary to darken the room, provided the spectrum was thrown out of the direct solar rays.

Mrs. Somerville next endeavoured to ascertain whether the other prismatic rays had the same property as the violet. Needles previously ascertained to be unmagnetic, exposed to the blue and green rays, sometimes acquired magnetism, though less uniformly and less quickly than in the violet ray: when magnetism was thus communicated, it seemed to be equally strong as in the former case. The indigo ray succeeded nearly as well as the violet. The exposed end, in almost every case, became a north pole. In no one instance was magnetism produced by the yellow, orange, or red rays, though in some instances the same needles were exposed to their influence for three successive days; neither did the calorific rays of the spectrum produce any sensible effect.

Pieces of clock and watch-spring were next tried with similar success, and were even found to be more susceptible of this peculiar magnetic influence than needles, possibly on account of their blue colour, or greater proportional surfaces. The violet rays concentrated by a

lens produced magnetism in a shorter time than the prism alone.

Experiments were next instituted by transmitting the solar rays through coloured media. Needles, half covered with paper, were exposed on a stone outside a window, under a blue glass coloured by cobalt, to a hot sun, for three or four hours. They were found to be feebly magnetic; but their magnetism was not permanently retained. In subsequent experiments, by an exposure of needles under the same circumstances, for six hours, a very sensible degree of magnetism was acquired, and remained permanent. The rays transmitted through the blue glass employed in this experiment blackened muriate of silver as powerfully as those transmitted through uncoloured glass; thus proving that it was freely permeable to the chemical rays of the solar spectrum. Green glass was also tried; and the rays which had penetrated it were likewise found to communicate magnetism. The white light of the sun produced no magnetic effect whatever on needles exposed to its influence.

ORIGIN OF TERRESTRIAL MAGNETISM.

Several causes have been assigned for the magnetic influence which the globe of the earth is found to exercise, not only over the magnetic needle, but also over currents of Voltaic electricity transmitted through conductors. Among the various substances which occupy the interior of the globe, it is extremely probable that chemical actions of different kinds are incessantly occurring. These actions will, for the most part, however, be very slow, and will continue with a certain degree of uniformity for very extended periods of time. They will occur more especially in the superficial strata of the earth, when the combined agencies of water, of atmospheric air, and of heat, are in constant operation. The influence of the solar rays on a surface of such vast extent must be very considerable: and excepting in the vicinity of the poles, every portion of that surface is

exposed in succession to their action, and acquires during that exposure a certain degree of heat, which heat is again lost by nocturnal radiation. Although the effect of the alternate changes of temperature may extend only to a small depth beneath the surface, yet considering their immense superficial extent, they may be sufficient to give rise to thermo-electric currents of considerable power.—It has been conjectured also, that these effects may be combined with an influence of another kind, more directly derived from the rotation of the earth on its axis, on the principle that all bodies have been found to exhibit magnetic polarity by rotation.

That electric currents do really circulate in different parts of the solid strata of the earth, is not merely matter of conjecture; the existence of such currents has been lately proved in the most satisfactory manner, by Mr. Robert Fox, in a paper "On the Electro-Magnetic properties of metalliferous veins," which was published in the Philosophical Transactions. Having been led from one theory to entertain the belief that a connexion exists between electric action in the interior of the earth, and the arrangement of metalliferous veins, he was anxious to verify this opinion by experiment. The first trials he made with this view were unsuccessful, but by persevering in his attempts, he soon obtained decisive evidence of considerable electrical action, in the mine of Huel Jewel, in Cornwall. His apparatus consisted of small plates of sheet-copper, which were fixed in contact with ore in the veins by copper nails, or else wedged closely against them, by wooden props stretched across the galleries of the mine. Between two of these plates, at different stations, a communication was made by means of copper wire, one-twentieth of an inch in diameter, which included a galvanometor in its circuit. In some instances three hundred fathoms of copper wire were employed.

The intensity of the electric currents was found to differ considerably in different places. It was generally greater in proportion to the greater abundance of copper ore in the veins, and in some degree, also, to the depth of the station. This curious fact may possibly afford the miner some useful indications as to the relative quantities of the ore which the vein contains, and also as to

the direction in which it is most productive. The electricity thus perpetually in motion, does not appear to be in any effect influenced by the presence of the workmen and their candles; nor even by the explosions of gunpowder in blasting.

Mr. Fox observes, that ores which transmit electricity have generally some conducting material interposed in the veins between them and the surface; a structure which appears to bear some analogy to the ordinary galvanic combinations. These electrical currents which pervade mines, were found to have various and frequently opposite directions in different parts of the same mine.

The metals are probably not the only substances capable of giving rise to electrical currents in the earth, for it is well known that galvanic combinations may be formed by arrangements of elements that are not metallic. The direction of each current will, of course, be determined by the relative position of the elements from which it is derived; but even if we suppose the arrangement of these elements to be fortuitous, a prevailing current will still result, arising from the difference of their actions; for it is infinitely improbable that, without a designed arrangement, the currents in opposite directions should be exactly equal so as to destroy one another. Irregularities of distribution probably exist with regard to the materials composing the interior of the globe; the resultant electro-magnetic action of the whole combination, being that of which we witness the effect, and which may be considered as due to electrical currents circulating in directions parallel to the magnetic equator round the surface of the earth.

Even in the irregularities incident to the magnetic forces derived from the earth, we may discover the operation of causes which are periodical in their operation. Thus the diurnal and annual changes of the variation of the needle may be traced to corresponding changes in the position of the different parts of the earth, with regard to the sun, in as far as these electric currents are dependent upon solar influence. The progressive changes in the variation, which embrace longer periods of time, are less easily accounted for, and appear referable to causes which act at greater depths below the surface of the

earth; and are probably connected with chemical changes taking place in the interior of the globe, of which we can possess no certain knowledge.

On the whole, then, it must be allowed that there are strong grounds for the belief that there subsists some mutual connexion, or rather an intimate relation and affinity, between the several imponderable agents, namely, *Heat*, *Light*, *Electricity*, and *Magnetism*, which pervade in so mysterious a manner all the realms of space, and which exert so powerful an influence over all the phenomena of the universe.

ELECTRICITY.

A GENERAL idea of a science may be more frequently communicated by a review of the rise and progress of that science, than by any other means. This remark applies to electricity with greater force than to many other branches of knowledge; and in drawing up the following historical sketch, attention has been paid to the extrusion of matter which has not instruction for its object.

The earliest account of electricity, artificially excited, of which we have any record, is carried as far back as six hundred years before the birth of Christ, when Thales, the Milesian, observed that amber, after having been rubbed, possessed the power of attracting light bodies, such as feathers, &c. We have no proof that much notice was taken of this fact; indeed it would appear of too little consequence to be much regarded; and it does not even seem to have been known that any other substance resembled amber in its attractive property after friction, till about three hundred years afterwards, when Theophrastus mentions that a stone, which he called the *lyncurium*, and which is supposed to be the same with what we now call the *tourmalin*, possessed the same peculiarity. From this period commences another chasm in the history of electricity, of nineteen hundred years' duration. The commencement of the seventeenth century may be considered the earliest era at which the science takes its date. The person who first contributed essentially to its promotion was Dr. William Gilbert, who in the year 1600, published a book, which contains a variety of electrical experiments, relative, however, merely to such substances as had the properties of amber, the whole of which class of bodies are now called electrics. These properties as yet excited no general interest; they became not the exclusive object of any one's attention, but only transiently arrested the notice of those whose re-

searches extended to every branch of knowledge, however unpromising and trivial its appearance. After the date of Gilbert's volume, additions continued to be made to the catalogue of electrics, but nothing of moment was observed further, till about seventy years afterwards; when the celebrated Robert Boyle greatly enlarged the number of electrics, and discovered that their effects were much increased by wiping and warming them before they were rubbed; and saw a faint specimen of the electric light, from some diamonds which he had rubbed to give them the power of attraction.

Otte Guericke, of Magdeburg, who was contemporary with Boyle, and justly famed as the inventor of the air-pump was eminently successful in his electrical pursuits. He constructed a globe of sulphur, to which he applied his hand while it was whirled round in a proper frame, by which means he had the pleasure of observing that he obtained an accumulation of electricity far beyond any former example, and which enabled him to perform a great variety of electrical experiments with considerable advantage. He discovered electrical repulsion, and not only saw in a state of intensity the electric light of which Boyle had seen but a glimpse, but heard the sound with which it is accompanied. He also observed that a feather when repelled by an excited electric, always keeps the same side towards the body which repels it, and that, after having been repelled it is not again attracted till it has touched some other body.

The torch of investigation into this subject, had now become distinctly lighted, and the number of discoveries increasing with considerable rapidity, kept curiosity alive, though without many fluctuations. Dr. Wall, by rubbing amber upon a woollen substance in the dark, produced considerable quantities of electrical light accompanied by a crackling noise; and he remarked that "this light and crackling seems, in some degree, to represent thunder and lightning." In 1709, appeared a treatise by Hauksbee, which possessed great merit. He repeated and confirmed the experiments of Dr. Wall, and noticed the sensation communicated to the hand by the electric spark. He introduced the important improvement of using a glass globe instead of a sulphur one, and among other new experiments, relates a method of rendering opaque bodies

transparent by means of electricity. He lined more than half of the inside of a glass globe with sealing wax; and having exhausted the globe, he put it in motion; when applying his hand to excite it, he saw the shape and figure of all parts of his hand distinctly, on the concave superficies of the wax within just as if only uncoated pure glass had been interposed between his eye and his hand. The lining where it was spread the thinnest, would but just allow the sight of a candle through it in the dark; but in some places the wax was at least the eighth part of an inch thick; yet the whole appeared equally transparent. The wax did not adhere to the glass in all places, but this seemed an immaterial circumstance. Pitch answered the purpose as well as sealing wax.

Sir Isaac Newton's discoveries attracted so much attention that electricity was kept for a time in the back ground; but soon after the decease of that great man, the opening that appeared for new discoveries in it again brought it forward. Hitherto the distinction between electrics, such as amber, glass, &c., which were excited by rubbing, and those bodies which were only capable of receiving electricity, appears to have been scarcely thought of. The distinct view of it was accidentally obtained by Stephen Grey, in 1729. After many ineffectual attempts to excite an electric power in metals, by heating, rubbing, and hammering, he recurred to a suspicion he had for sometime entertained, that, as a glass tube, when rubbed in the dark, communicated its light to various bodies, it might possibly at the same time communicate to them an electricity or power of attracting light bodies. To examine into this matter, he provided himself with a glass tube, three feet five inches long, and nearly one inch and two-tenths in diameter. To each end was fitted a cork, to keep the dust out when the tube was not in use. His first experiments were made with a view to determine whether the tube would attract equally well with the ends closed by corks, as when they were open. In this respect there was no difference, but he found that the corks attracted and repelled light substances even with rather more power than the tube itself. He then fixed an ivory ball upon a stick of fir about four inches long, and thrusting the end of the stick into one of the corks, he found that the ball obtained a strong power of attrac-

tion and repulsion. He varied the experiment, by fixing the ball upon long sticks, and upon pieces of brass and iron wire, and always obtained the same result; also when he suspended the ball by a packthread from a balcony twenty-six feet high, he still found, at this and all other heights, that by rubbing the tube, the ball acquired the same power as in his first experiment.

Grey's next attempt was to ascertain whether electricity could be conveyed horizontally as well as perpendicularly. With this view he fixed a cord to a nail which was in one of the beams of the ceiling, and making a loop at that end which hung down, he inserted his packthread with the ball at the end of it, through the loop of the cord, and retired with the tube to the other side of the room, but in this state he found that his ball had no power of attraction. A friend of his, to whom he related his disappointment, suggested that the supporting packthread, from its coarseness, might intercept the electric power, and proposed to substitute a thread of silk. Upon this change being made in the apparatus, the experiments (which were made by Grey and his friend conjointly,) completely succeeded, and the ivory ball showed signs of electricity at the distance of 147 feet from the glass tube. In subsequent experiments they increased the conducting cord, till at length the silken thread supporting it broke. As they attributed their success, since the adoption of the silken thread, entirely to the fineness of that material, they naturally conjectured that brass or iron wire would be still more advantageous; upon making the trial, however, they were completely disappointed, for they found that the ivory betrayed not the slightest evidence of electricity. They therefore again resorted to the use of silk, but used it thicker than before; and by this means conveyed the electric power, without any apparent diminution to the distance of 765 feet.

Such were the experiments which immediately led to the important truth, that though a great number of bodies had the power of conducting the electric energy, yet there were other bodies which entirely stopped its course; and as the former were called *conductors*, the latter were called *non-conductors*. It was soon found that those bodies which showed signs of electricity by rubbing were always non-conductors, and that those which could not

be brought to this state, were conductors. Grey continued a zealous electrician to the period of death, and made many interesting discoveries. In particular, along with his friend, he discovered the method of insulating bodies which were electrified, by placing them upon a non-conducting body, and thus preventing the electricity they have received from immediately flying off.

The grand discovery made by Grey and his friend had been announced but a short time, before another, scarcely less important, was made by Du Fay, who was intendant of the French King's gardens. It arose from casually observing, that though an excited glass tube repelled a piece of gold leaf, yet an excited piece of gum copal eagerly attracted the same material. Du Fay found upon trial, that sealing-wax, sulphur, resin, and a number of other substances, produced the same effect as gum copal. To the electricity of those substances which attracted the gold leaf after excitation he gave the name of the *resinous* electricity, as they were most of them resins; and to the electricity of glass he gave the name of the vitreous electricity, for he entertained not a doubt but their nature was as opposite as their effects. Among other experiments, he found it impossible to excite a tube in which the air was condensed; and in repeating Grey's experiments, with a packthread, he perceived that they succeeded better by wetting the line. Hair being a non-conductor, Grey had insulated and electrified a boy by suspending him with hair lines; on this, Fay, in repeating this experiment of the effects of electricity on the animal body, suspended himself by silken cords; in this situation, sparks of fire were drawn from him, on his being touched by any one, and both he and the other person felt a sharp pain at the instant of contact, which was accompanied by a snapping noise.

When another person, by holding a rod of metal, touched the one that was electrified, the spark was drawn as before. From this instance of the accumulation of electricity, and its being drawn off by metal, Grey inferred, and in fact, his former experiments in electrifying insulated substances, has proved, that electricity might be collected in metal, as well as the animal body, and drawn off, during a short interval, as it was wanted. This suggested to him the propriety of that

part of an electrical machine now called the prime conductor, which he formed by suspending a piece of metal near his excited glass tube, and was enabled to draw sparks from it. The method of making the prime conductor in the form of a tube was first adopted in Germany, in 1742, where the use of the globe, invented by Hauksbee, was revived, and the conductor was at first suspended by a man standing upon casks of resin, but afterwards it was suspended by silken lines. In Germany, also, about the same time, a woollen rubber was used instead of the hand to excite the globe.

Electricity had now become a part of philosophy, and it had become the duty of some to study that they might teach it; whilst others, who were disposed to the acquisition of knowledge, were incited by the desire of proving what others had asserted, or the higher motive of finding out something new. In this conflict of exertion a discovery was made that may justly be considered as forming an epoch in the history of science, which it immediately raised to an extraordinary degree of estimation. This discovery consisted in the art of accumulating electricity, by what is now called the *Leyden phial.* Towards the close of the year 1745, Von Kleist, dean of the Cathedral of Caminin, made an experiment, of which he sent the following curious account to a friend in Berlin. "When a nail, or a piece of thick brass wire, &c., is put into a small apothecary's phial, and electrified, remarkable effects follow: but the phial must be very dry and warm. I commonly rub it over beforehand with a finger on which I put some pounded chalk. If a little mercury, or a few drops of spirits of wine are put into it, the experiment succeeds the better. As soon as the phial and the nail are removed from the electrifying glass, or the prime conductor to which it hath been exposed is taken away, it throws out a pencil of flame so long, that with this burning machine in my hand, I have taken above sixty steps in walking about my room. When it is electrified strongly, I can take it into another room, and there fire spirits of wine with it. If, whilst it is electrifying, I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders. A tin tube, or a man placed upon electrics, is electrified much stronger

by this means than in the common way. When I present this phial and nail to a tin tube, which I have, fifteen feet long, nothing but experience can make a person believe how strongly it is electrified. Two thin glasses have been broken by it." In this experiment, as the phial was of small dimensions, and as the circumstances essential to its greatest effects, were not combined, because they were unknown, the power of the electricity accumulated was inconsiderable; but, soon afterwards, the art of giving a strong shock was discovered in Holland, because the vessels employed happened to be larger. As it was known that the air, or the partial floating in it, abstracted the power of electrified bodies, so that even insulation was no remedy against their being in a short time deprived of it, an idea suggested itself to Muschenbrok, and some of his friends, that if the electrified body were entirely surrounded by a non-conductor, the dissipation of the electricity would in a great measure, be prevented. To realise this idea, a quantity of water was put into a bottle, and electrified till it was thought to be fully changed; but here the original invention of the experiment was lost sight of, by an unexpected result which swallowed up all their attention. Happening to hold the bottle in one hand, while he endeavoured to disengage it from the conductor with the other, he suddenly received a shock, which shook many of his joints, passed through his breast, and in a great degree, stunned and terrified him. In this manner was first discovered, what still continues to be called the *electric shock*. It excites a smile, to observe the terms in which the shock is spoken of, by several of those who first submitted to its effects. One who tried the experiment with a thin bowl, wrote to his friend afterwards, that he felt himself struck in his arms, shoulders, and breast; that he lost his breath for a time, and did not feel himself well again for the space of two days. He adds, that he would not have taken a second shock for the whole kingdom of France. Other philosophers, however, were found, who had the resolution to take several shocks of great intensity; and one of the most hardy wished that he might die by the electric shock, in order that his death might furnish an article for the memoirs of the Parisian Academy.

After the art of giving a shock by means of a phial or jar had been discovered, the art of combining several jars, so as to unite their powers in one discharge soon followed, and this improvement constituted what is now called a *Battery*. It was made by Dr. Franklin, and resulted from his reflections on the phenomena of the Leyden phial with a conducting substance which communicated by a wire with the person who discharged it, the strength of the shock was exceedingly increased; and that unless some conducting substance was in contact with the outside of the jar, no charge could be given. Dr. Franklin, in accounting for this circumstance, suggested the idea that a charged phial or jar contained no more electricity than before; but that as much was taken from one side as the other had above its natural portion, and that to discharge it, nothing more was necessary than to make a communication between the two sides, and the equilibrium being by this means restored, no signs of electricity remained. He also demonstrated by experiments, that the electricity did not reside in the coating, as had been supposed, but in, or upon the glass itself. After a phial was charged he removed the coating, and found that upon applying a new coating, the shock might be received. When to any body or surface, was attributed the property, according to this theory, of having more than its usual portion of electricity, the Doctor proposed to distinguish its state by the term *plus* or *positive;* when the body or surface had less than its usual share of electricity, its state was distinguished by the term *minus* or *negative.* These terms answered the same purpose and expresed the same things as those of vitreous and resinous, but they were supposed to be so much more appropriate, that their admission into the language of the science soon became complete. It may only therefore be necessary to remark here that bodies electrified plus or positively, are those possessed of vitreous electricity; while those electrified minus or negatively, are possessed of what was termed the resinous electricity. The former seek every opportunity of imparting, and the other of receiving electricity. This consideration of the subject induced the supposition, that if the insides of several jars were connected by means of a conducting substance, and their outsides connected with each other in like manner, they would receive and impart a charge like

a single jar, with the difference only of power, which would be increased in proportion to their number and size; and thus a battery of any force could be obtained. By a battery it was found that small animals might be instantly killed, as if struck by lightning, and these convincing examples of its power induced philosophers, where life was concerned, to be more cautious in the use of it than they had been with the jar; but experiments of other kinds were prodigiously multiplied. It was proved that the electric matter might be conveyed to distances much exceeding what had yet been conjectured; Dr. Watson, bishop of Llandaff conveyed it four miles, a distance which it traversed instantaneously. In another experiment made by the Doctor the electric matter was conveyed by a wire through the river Thames, and spirits were kindled by it after it had run this watery circuit. In other experiments it was conveyed nine miles, and a shock has been sent through 1800 men with a force inconceivably rapid.

The field for electrical experiments had now become very extensive, but there still wanted data that might lead to some knowledge of the nature of the principle thus brought into action, and of the various circumstances that were essential to its production. Dr. Watson, however, made some experiments which tended to these points. Having rubbed a glass tube while he was insulated, by standing on a cake of wax, in order to be electrified, he found that no snapping could be drawn from him by another person who touched any part of his body; but if a person not electrified held his hand near the tube while it was rubbed, the snapping was very sensible. He also observed that if an electrical machine, and the person who turned it, were suspended by silk, no fire was produced; but if he touched the floor with one foot, the fire appeared upon the conductor. From these and other experiments of a similar nature he inferred, that glass tubes and globes only afford the means of obtaining the electric energy, which does not reside in them, but is derived by them from some external source.

Dr. Franklin's explanation of the phenomena of the Leyden jar, and of positive and negative electricity, was given in the course of a correspondence with Mr. Collinson, in England, to whom he also communicated a curious and important observation on the power of points in drawing

and throwing off the electric matter. The first intimation of the latter particular he derived from one Thomas Hopkinson, who electrified an iron ball of three or four inches in diameter, with a needle fastened to it, expecting to draw a stronger spark from the point of it; but his expectation was entirely frustrated.

The attention of those inclined to philosophical pursuits in Philadelphia, had been directed towards electricity by the care of Mr. Collinson, who, in 1745, had sent to the Library Company in that city, an account of the extraordinary experiments then performing in Europe, together with a tube, and directions for its use. But Franklin's eagerness in the research, and his success in making discoveries, exceeded that of all his friends. In 1749, he suggested an explanation of the phenomena of thunder-gusts, and of the aurora borealis, on electrical principles; he pointed out many particulars in which the lightning and electricity agreed; and in adverting to the power of pointed rods in drawing off lightning, he supposed that pointed rods of iron fixed in the air when the atmosphere was loaded with lightning, might, without noise or danger, draw from it the matter of the thunderbolt into the body of the earth. He says, "The electric fluid is attracted by points. We do not know whether this property be in lightning; but since they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewise in this: let the experiment be made." The earliest observation, it will be recollected, on the similarity of electricity and lightning, was made by Dr. Wall. On the supposition of the identity of lightning and electricity, Franklin immediately saw and pointed out, that houses and ships might be secured from lightning by pointed iron rods, which should rise some feet above the most elevated part of them, and descend some feet into the ground. But while he postponed the completion of his views, on account of the want of a proper building in Philadelphia for his purpose, they were realized in France, by the following means, and produced incredible surprise.

Franklin having communicated regular accounts of his proceedings and theories to his friend Collinson, who published them for the information of the world, they were soon extensively circulated, and translated into

different languages. In France the principles of Franklin, and several of the experiments by which they were supported, soon became familiar to some of the principal philosophers, and several of them, among whom were D'Alibard, and De Lor, determined separately to undertake the experiment. Franklin had proposed for bringing lightning from the clouds. D'Alibard prepared his apparatus at Mary-la-ville, about five or six leagues from Paris: it consisted of an iron rod forty feet long, the lower extremity of which was brought into a sentry-box, where the rain could not come; while on the outside it was fastened to three wooden posts by long silken strings defended from the rain. In his absence he entrusted the care of the machine to a joiner of the name of Coissier, a man of sense and courage, whom he furnished with directions how to proceed in case of a thunder-storm. On the 10th of May, 1752, Coissier heard a clap of thunder between two and three in the afternoon. He ran to the apparatus, for D'Alibard was then absent, and drew sparks from the rod, in the presence of several witnesses. Eight days afterwards, De Lor proved equally successful with his apparatus.

While the laurels with which posterity should crown the memory of Franklin were thus springing up in Europe, where his character now became emblazoned with a general admiration of which he was ignorant, he had himself devised the means of easy access to the elevated regions of the air. He concluded that a pointed rod of a moderate height would not answer, and therefore did not try one; but it occurred to him that a common kite, such as children amuse themselves with, would reach any height he wished. He accordingly prepared one of silk, that it might not be injured by rain, the straight piece of wood up the middle of it was pointed with iron, and at the first approaching thunder-storm, he went to a convenient situation for raising it. He was assisted by his son to whom alone he communicated his intentions, possibly with a view to avoid the appearance of premature boasting if he should be unsuccessful. The string of the kite was of hemp as usual, except at the lower end, which was of silk. Where the hemp terminated was fastened a key. After the kite had been raised, a thunder-cloud

passed over it; but no electricity appeared. Disappointment appeared to be impending; when suddenly some loose fibres of the string appeared to stand erect and to avoid one another, as if they had been suspended by the conductor of a common electrical machine; he presented his knuckle to the key, a strong spark ensued, and as soon as the string became wet, the supply of electricity became copious. He afterwards prepared an insulated iron rod, to draw the lightning into his house, and by means of real lightning, he performed all the experiments usually executed by means of electrical machines. This memorable experiment was tried in June, 1752: the French philosophers had therefore the precedence in point of time; but they only trod in the path which Franklin had explicitly pointed out.

When the method of giving the electric shock had just been discovered, such was the influence of the feelings it inspired, that many of those who received it appeared to think no terms too extravagant to convey an idea of the violent effects of a charge which may be borne by a child; but now the time for real terror had arrived; and many who incautiously adventured to bring down the ethereal fire, suffered much by violent shocks, while they incurred the most imminent hazard. In one instance a fatal catastrophe ensued, and we shall record it for the sake of strongly impressing upon the young electrician the necessity of caution. On the 6th of August, 1753, Professor Richman, of Petersburg, was making experiments on lightning drawn into his own room. He had provided himself with an instrument for measuring the quantity of electricity communicated to his apparatus, and as he stood with his head inclined to it, Solokow, an engraver, who was near him, observed a globe of blue fire, as large as his fist, jump from the instrument, which was about a foot distant, towards his head. The professor was instantly dead, and Solokow was also much hurt. The latter could give no particular account of the way in which he was affected; for, at the time the professor was struck, he stated, that there arose a kind of steam or vapour which entirely benumbed him, and made him sink down to the ground, so that he could not even remember to have heard the clap of thunder, which was very loud. The globe of fire was attended with an ex-

plosion like that of a pistol; the instrument for measuring the electricity was broken to pieces, and the fragments thrown about the room. Among other effects of the lightning in the chamber, the door-case was found to be half split through, and the door torn off, and thrown into the room. A vein was opened in the professor's body twice, but no blood followed; after which attempts were made to recover life by friction, but in vain; upon turning the body with the face downwards, a small quantity of blood ran out at the mouth. There appeared a red spot on the forehead, from which came some drops of blood through the pores, without breaking the skin. The shoe belonging to the left foot was burst open, and on uncovering the foot, at that part was found a blue mark; whence it was inferred that the electric matter, having entered at the head, made its way out again at that foot. Upon the body, particularly on the left side, were several red and blue spots, resembling leather shrunk by heat; and many more became visible over the whole body, particularly over the back. That upon the forehead changed to a brownish red; but the hair of the head was not singed. In the place where the shoe was unripped, the stocking was entire; the coat also was wholly uninjured, and the waistcoat was only injured on the fore-flap where it joined the hinder. On the back of Solokow's coat appeared long narrow streaks, as if red hot wires had burned off the nap. In forty-eight hours the professor's body was so much corrupted, that the removal of it was exceedingly difficult.

But it has been left to our own times to effect the most important discovery of the utility of electricity—the electric telegraph: by which an instantaneous communication is established between every town and village of any consequence throughout the United Kingdom. This invention was finished in 1848; it is conducted by means of five wires of zinc and copper laid in tubes under ground, and connected with metallic plates at the various stations of each town. By this discovery, intelligence is immediately conveyed throughout the length and breadth of the land. For example, when her majesty Queen Victoria opened her parliament in 1848, the printers in various parts of the kingdom, hundreds of miles distant from London, were actually employed in putting her speech in

type while she was speaking. The speech was telegraphed as it was delivered, six or eight words at a time; and the inhabitants of the remotest districts were gratified in having it in their power to peruse the speech from the throne, almost as soon as the denizens of London themselves.

We had scarcely ceased to wonder at the achievements of the electric telegraph,—conveying intelligence between places, hundreds of miles apart in the twinkling of an eyelid, when we were called upon for wonderment at a still more extraordinary invention—it is that of the "*Electric Light.*" Several trials of this light have been made; and it is averred that it will supersede the use of all other artificial lights; that by its intense brilliancy darkness will be dispelled; that in point of safety, cheapness, and efficiency, it will far surpass all other inventions for illuminating; that there is no smoke, no vapour; that it can be lighted up and extinguished by the touch of a child; that it is inexhaustible, and may yet be put out in a moment. It is expected to be seen careering as a pillar of fire on the railways, and spreading its rays across the turbulent waves from the distant steamer. It will be from the lighthouses a gem bound on the dusky brow of night. Such are the fond expectations. Patents have been secured, and companies are in course of organization for dispensing the blessings of this wonderful invention.

REMARKS ON ELECTRICITY.

Electrical Clock.—This machine, which is exhibited in Geneva, is especially remarkable on account of its extreme simplicity, is composed only of a pendulum, a large wheel, two escapements, and a quadrature. Such are the visible parts: we must, however, suppose that a pinion and a wheel make the communication between the great wheel and the quadrature. The pendulum at each vibration, causes one of the escapements to advance the great wheel one tooth, which, after this movement has a pause making the dead round. As there is no metallic

moving power to set the machine a-going, we find, on examining, what keeps up the motion, that the pendulum, which is almost out of proportion with the clock, descends into a case; and there, at each vibration, the ball or bub, which is furnished with a conductor, approaches alternately two poles, to which voltaic piles supply their portion of electricity. So that the pendulum, when once put in motion, retains it by means of the electricity alternately drawn from the two poles. This machine, which is equally simple and ingenious, is worthy of the attention of the artist. Perhaps other interesting results may be obtained by employing the electric fluid as a moving power, however slight the force such an agent may seem capable of communicating.

In drawing up the preceding sketch, we omitted to mention that although the chief technical terms belonging to the subject have been in a good measure explained, but to render the reference to them more easy, we shall here explain them more fully.

All bodies which admit electricity to pass through them, such as gold, silver, copper, platina, brass, iron, quicksilver, lead, &c, are called *conductors of electricity;* the same bodies are often called *non-electrics.*

All bodies which are impermeable to electricity, such as glass and vitrifications, precious stones, amber, jet, sulphur, wax, silk, cotton, resinous substances &c., are called *non-conductors of electricity;* they are also called *electrics* with almost equal frequency.

We have already observed that electricity is found to be of two kinds, which are generally distinguished by the appellations of positive and negative. In what the difference of these electricities consists has been much contested; but we coincide with Dr. Franklin, who argues that when bodies are electrified positively, their electricity is redundant or greater than their natural quantity; when they are electrified negatively, he supposes that part of their natural quantity of electricity is abstracted.

The cause of electricity is supposed to be a fluid, which is therefore called the *electric fluid.*

Any electric body, the surfaces of which possess the two different electricities, is said to be *charged.*

ELECTRICAL APPARATUS.

We will now notice shortly, the principal machines by which electricity may be accumulated and accomodated to the purpose of experiment; and then proceed to the consideration of the theory of electricity.

The simplest kinds of electrical apparatus, such as glass tubes, rolls of sealing wax, cakes of resin, &c., require no separate description, as they will be sufficiently understood by their names.

The cylinder machine, which is most commonly used, is better known by the name of the *Electrical Machine*. The cylinder, conductor, rubber, and pillars should, when it is in use, be perfectly dry, and to ensure this they should be rather warm than otherwise. The machine is supposed to be in order and a communication made between the rubber and the ground by means of a chain or piece of wire attached to it; on turning the cylinder, the electric fluid, in the form of sparks, accompanied by a snapping noise, may be drawn from the prime conductor by presenting to it the knuckle or any blunt uninsulated conductor. If any pointed body, such as a needle, be presented to the conductor while the cylinder is turned, a star or globule of light will be seen at the point, but no noise will be heard.

The *Plate Machine*.—When glass was first used as the electric of a machine, the form of a globe was adopted; but afterwards the cylinder, as above mentioned, was found more convenient and economical. Dr. Ingenhouz, however, introduced the use of a flat cylinder plate, turning on a horizontal axis in the manner of a wheel, and the machine thus constructed has many good properties; it is simple, elegant, compact, and powerful. The most powerful electrical machine ever made was of this description, for the museum at Haarlem.

The *Electric Jar*.—Electricity, derived from the conductor of a machine, is accumulated, and for a time preserved by means of electrics coated with conducting substances. Glass is the electric most usually employed, and the form generally selected is that of a jar. "Leyden

phial" is synonimous with "electric jar." In selecting jars for electrical purposes, care should be taken to have the glass equally thick in every part. When a jar is defective in this respect, it will break in the thinnest part if strongly charged.

The *Electric Battery* is formed by combining a number of jars, in a wooden box of a size adapted to the number of jars it is to contain, not quite so deep as the jars are high, divided into compartments, each of which will receive only one jar. A powerful battery may be formed of wine bottles; but they must be coated and furnished with a wire in the same manner as ordinary jars.

Electricity may be obtained in a great number of ways as well as by friction, insomuch that we have reason to consider this power as a universal agent of nature. 1. It is produced by the heating or cooling of a variety of substances. 2. By the evaporation and condensation of vapour. 3. By the natural changes in the atmosphere. 4. By the will of certain animals. 5. By the action of certain bodies on each other when in contact.

The *Electricity evolved by heating and cooling* has been sometimes called spontaneous electricity. If sulphur be melted in an earthen vessel, and then left to cool in the same vessel upon conductors, it will, upon being taken out after it is cold, be found strongly electrical; but if left to cool upon electrics, no such effect ensues. If sulphur be melted in a glass vessel, and left to cool, both the glass and the sulphur acquire a strong electricity; but the electricity is stronger when they are cooled upon electrics than when cooled upon conductors; and if the glass vessel be coated with metal, the electricity acquired is strongest of all.

The *Electricity evolved in evaporation and condensation of vapour.*—Volta discovered that bodies from which water had evaporated showed signs of negative electricity, by which it appears that water, in the state of vapour, retains a larger portion of the electric fluid than in the state of water. Exceptions have, however, been taken to this rule: 1. If water be evaporated by contact with a red hot piece of rusty iron, it will leave the iron electrified positively; but the iron will be negatively electrified if not rusty. 2. If water be evaporated by throwing into it impure red hot glass, (such as the glass of

bottles,) the vessel, or the remaining water will be electrified positively.

Atmospheric Electricity.—Since Franklin and his contemporaries first drew lightning from the clouds, and exhibited with it the whole series of electrical phenomena, no experiment has ever been devised, which could throw a shadow of doubt on the identity of lightning and electricity. Accordingly, lightning is only to be considered as a name for a vast accumulation of electricity; or electricity as a name for small quantities of lightning. When we consider the sharpness of a spark supplied by a few inches of glass, we cannot hesitate to allow that the effect of the spark drawn from a thousand acres of cloud must be violent in the extreme.

The atmosphere almost at all times affords signs of electricity, and it may be proper to advert here to the means commonly used to discover it. Cavallo's electrometer is a very useful instrument for this purpose. By holding it up a few feet above the ground the pith-balls will gradually diverge, and the kind of electricity may be ascertained by touching it with any excited electric, observing that the electricity of the instrument in this case, is the contrary of that of the atmosphere.

Instruments have been invented, called multipliers and doublers of electricity, intended to be used where extreme delicacy of examination is proposed; but the action of these is rather of a dubious nature, and we shall pass on to a short notice of

The *Electric Kite*, which, as we have already observed, differs in no respect from those used among children, except that the paper is covered with drying linseed-oil, to prevent its being destroyed by the rain, and a slender wire is interwoven with the string to render it a better conductor. It is, however, doubtless known to every one, that there is a considerable difference among children's kites in their flying properties; some of them, under every favourable circumstance of wind and size, can scarcely be raised or kept aloft by any exertion, so that the pertinacity of infantine perseverance, in affairs of sport, is almost exhausted in attending to them. We shall therefore give the proportions that will certainly answer well, and as these may be observed with so much facility, we presume it will not be required that we

should devote a sentence to the consideration of how much they may be deviated from without hazarding the convenience of raising the machine. The straighter and the bow, should, when the latter is open, be of the same length, reckoning the length of the straighter from the place where it is notched to the bow. By this means when the bow is in its place, the cord which connects its extremities, passes over the straighter at the distance of one third of its length of the latter from its end; and the tapering of the kite therefore commences at two thirds of its length from its pointed extremity. The cord to which the cord for raising the kite is attached, is fastened by both ends to the straighter, and at one sixth of the whole length of the kite from the extremity. The length of the cord may be about equal to that of the straighter. The cord, the length of which regulates the distance of the flight of the kite, must be attached to such a part of the cord fastened to the straighter, that the kite if suspended by it, without a tail, shall remain horizontal, that is, it shall be just opposite the centre of gravity of the kite; and if the weight of paper on each side of the straighter is not equal, it should be made so by putting on additional pieces. The tail of the kite should be at least seven times the length of the straighter, and it should be loaded in about twenty different places with some such material as rolls of paper, and a ball or heavy roll of the same kind at the extremity. The proper weight of the tail is easily ascertained by a few trials. The straighter should be made of fir, and the bow cannot be made of any thing better than a light hoop. A kite thus constructed will be easily raised with a moderate wind to a great height. A kite four feet high is very convenient for electrical purposes.

In an electrical point of view the whole power of the kite consists in the string; it is, therefore, of little use to coat the straighter with tinfoil, or tip it with iron as some have proposed; but it is important to make the string a good conductor. For this purpose the simplest mode is to wet it; but it is better still, to use with two threads of common hemp one of the copper threads used for trimmings.

The highest idea which the ancients could form of omnipotence, comprised the exclusive ability of directing

the thunderbolt; the power of which they considered to be absolutely irresistible, and the command of it immeasurably removed from human control. If then weak man venture to interfere with this astonishing agent of nature, let him remember its tremendous power, and not, for a moment, forgo the precautions that ensure his safety. In serene weather there never is any danger in raising the kite; but it is always unsafe to raise it during a thunder-storm, or while black clouds are hovering overhead; for the quantity of electricity brought down will often be very great, although there may be no thunder. When the electricity during a storm is intended to be observed, the kite should be raised while the air is yet tolerably clear: at the lower end of the conducting line should be attached three or four yards of silk cord covered with wax, that it may not, by getting damp, readily become a conductor. From the termination or some other part of the conducting line, a chain of sufficient length to reach the earth should be fastened, or instead of it, when jars are to be charged and other experiments are to be made, a slender wire may reach from the conducting line to an insulated prime conductor. This conductor should be furnished with a quadrant electrometer, that the strength of the electricity may be determined by inspection. The wire connecting the string of the kite and the prime conductor should not be stretched, to prevent the motions of the string or the conducting line from throwing down the conductor. In making experiments with an insulated string, especially when a storm is apprehended or actually present, it would be proper to have a rod of iron or some other good conductor in direct communication with the earth, and within an inch or two of the string, so that notice would be given of the descent of any unusual quantity of electricity by the snapping between the conductor and the string, and the operator would have time to provide for his safety.

After experiments with the electrical kite had proved that lightning could be drawn from the clouds, it ceased to be a doubtful question whether buildings might not be saved from destruction by lightning, if they were furnished with proper conductors. But a controversy arose as to the best form for them. It was maintained by one party that they should have blunt terminations; by another

that they should be pointed. A number of experiments made under the inspection of the Royal Society, decided the question in favour of pointed conductors, and no others are now in use.

An effective conductor should rise eight or ten feet above the highest part of the edifice it is intended to secure, and should terminate in several short branches, each of which must be pointed, in order that if one or more be melted by the lightning, the rest may perform the office assigned them. The conductor should not be smaller than half or three quarters of an inch in diameter, and as its effects would be injured by rust, the upper part of it should be copper. It should not descend very close to the side of the building, and care should be taken to direct it from the house towards the foundation, and terminate it if possible in moist earth or water under ground.

Personal security, during a thunder-storm forms another object of important consideration. Persons apprehensive of lightning should sit in the middle of a room, not under a metal lustre or any other conductor, and place their feet on another chair. A precaution of this kind is the easiest that can be observed, and ensures a high degree of safety. But the place of most perfect safety is the cellar, and especially the middle of it; for when a person is lower than the surface of the earth, the lightning must strike it before it can reach him. It is therefore most probable that it will become immediately diffused and not enter the cellar, especially if it be not damp.

The best situation for a person who happens to be in the fields during a thunder-storm, is, not immediately under a tree, but within a short distance of it, as the lightning generally strikes first the highest and best conductors.

Animal Electricity. There are three species of fish which possess the power of giving an electrical shock; viz., the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*.

The *Torpedo* has been known from the most ancient times, but the wonderful accounts of its power were till recently regarded as fabulous by those who had not witnessed them. The torpedo is a flat fish, of the ray tribe, very seldom exceeding twenty inches in length and twenty

pounds in weight. It inhabits the Mediterranean and the North Seas. If the torpedo either in the water or out of it, be touched with one hand, it generally communicates a slight shock to the hand; but the sensation is felt in the fingers of that hand only. If the torpedo be touched with both hands at the same time, one being applied to its under, and the other to its upper surface, a shock will in that case be received, which is exactly like that given by the Leyden phial. The animal is supposed to stupify its prey by this singular faculty.

The *Gymnotus Electricus*, or the electrical eel, is generally of the length of three or four feet, of an unpleasant appearance, and much like a large eel, but thicker in proportion to its length, and always of a blackish brown colour. It is found in the hot climates of Africa and America. This animal has the power of giving an electric shock to any person, or to any number of persons who join hands together, the extreme person on each side touching the fish.

Of the third fish capable of giving the shock, but few particulars are known. It is called the *Siluras Electricus*, and is found in the rivers of Africa. It is sometimes found to exceed twenty inches in length. The body of this fish is oblong, smooth and without scales; the electric organ seems to be towards the tail, where the skin is thicker than on the rest of the body. It is merely said in general that it has the power of benumbing like the torpedo, but we have seen no details of experiments made with it.

Electrical Cohesion.—The force with which electrified bodies remain in contact, has, instead of attraction, been called electrical cohesion. An amusing instance of this is seen in Symmer's experiments on silk stockings. He had been accustomed to wear two silk stockings on the same leg, one of them white, the other black. When these stockings were drawn off together, nothing remarkable appeared; but if, while they were both on, he rubbed his hands several times over them, and then drew off the outer or black one by itself, he heard a crackling noise, and in the dark perceived sparks of fire between them. When the stockings were separated, and held at a distance from each other, both of them appeared to be highly excited; the white stocking positively, and the black

stocking negatively. While they were kept at a distance from each other, both of them appeared inflated to such a degree that they exhibited the entire shape of the leg. Two black or two white repelled each other with considerable force; but a white and a black one, would, if permitted, rush together with surprising violence; their inflation subsiding at the same time, and entirely ceasing when they were in contact. On separating them their electricity was renewed. At first Symmer found that it required a force of from one to twelve ounces to separate them; and at another time they required seven ounces to separate them, which was twenty times the weight of the body that supported it. Electrical effects will be obtained by rubbing with the hand any small pieces of black and white silk in like manner.

Medical Electricity.—In the infancy of electricity accounts were multiplied of cures next to miraculous performed by means of this newly acquired power; but upon closer investigation it appeared that most of these either had no existence, or were exaggerated by weak or interested men, and that mischief rather than benefit had occasionally been produced. The error of the early electricians consisted in giving strong shocks, which experience has shewn to be nearly in all cases improper. "One thing, however," says Cavallo, "appears to be a little remarkable in favour of electricity as a medicine, that though it has often fallen into the hands of very unskilful and injudicious persons, who have applied it at random in all cases, without being capable of distinguishing either the nature of the disorder, or the degree in which it ought to be administered, yet it has seldom been known to be attended with any bad effects; the patient generally has been relieved, and very frequently cured, but the ill consequences have been even more rare than those of inoculation. Electricity differs from other medical applications in this, that it acquires not so much a thorough knowledge of the distemper, as a peculiar nicety in conducting the operation. For, however paradoxical this may appear, it is certain that the electric shock is by no means prejudicial to persons in health, and therefore to electrify a sound part of the body along with a diseased one can do no harm. The degree of electrization must be regulated rather by the patient's feelings, than by the

species of disease, and therefore nosology is not an indispensably necessary branch of science to the medical electrician. There can be no doubt, however, that medical electricity will have every chance of being best applied, as well as improved by skilful physicians and surgeons, whose knowlege of anatomy as well as nosology, will enable them to direct the electrical fluid to the most proper part of the body, and to pass it through the most minute vessels, according to the nature of the disease, and the part of the body affected."

Insensible perspiration is one of the most important functions of the animal frame; and as it is promoted by electricity, it may fairly be inferred that electricity promises to render signal services in cases which will yield to no other power. The power of electricity over the blood, also, is evidenced by the fact of its increasing the force of its circulation. Thus on insulating and electrifying persons who have been bled in the arm, the blood has sprung up to a greater distance than before. The same treatment will cause a fresh wound to bleed anew.

The medical application of electricity requires but few instruments in addition to the common electrifying machine. An electric jar, united with Lane's electrometer; an insulating stool of such a size that an ordinary chair may be set on it for the patient to sit in, and a pair of simple instruments called directors, are all that are necessary.

In the medical application of electricity it is of importance to begin gently, and to persevere for some time. At first the electric fluid should be drawn by a metallic point, the person being insulated and connected with the prime conductor, and the metallic point communicating with the earth. If after some days trial no abatement of the disorder ensues, and the electrification has not the favourable effect even of imparting an agreeable warmth, the electric fluid may be drawn by means of a wooden point; next to a wooden point are sparks, and after these low shocks. The electrification, whether in using the directors or otherwise, may be made through the clothes, unless they be very thick. In administering small shocks through thick clothing, it will be proper to pass metallic points through the clothes so as to be in contact with the skin.

In disorders of an inflammatory nature, electricity, as it is a stimulant, should not be resorted to, unless at the commencement of those of a slight and local nature, as of a catarrh, inflammation of the eyes, and swellings where suppuration has not actually commenced. In chronic rheumatism, and chronic complaints in general, electricity may always be applied with safety, and even if it should not effect a cure, it seldom fails to afford relief. The toothache, when of rheumatic origin, and unattended with caries, seldom fails to yield to this application. Dr. Samuel Perry, of New Bedford, America, successfully applied electricity in two instances of locked jaw, after bleeding, cathartics, antismodics, the warm bath, and opium applied internally and externally had totally failed. In one case the complaint was entirely removed by three shocks, in the other by an occasional shock for a few days.

There is one method of applying electricity, the value of which has not as yet been fully ascertained; it is that of electrifying a bath, whether of warm or cold water. This may be accomplished by lining the bath with non-conducting substances.

GALVANISM.

THE electricity evolved by the mere contact of conducting substances is called *galvanism;* a name given to this branch of science in compliment to Galvani, a celebrated physiologist of Italy, whose investigations first directed the attention of the public to the phenomena it comprehends.

While Professor Galvani was employed in dissecting some small animals, his wife observed that a dead frog, lying near the prime conductor of a common electrical machine, was much agitated when one of his assistants happened to bring the point of a scalpel near its crural nerves; Galvani, on being apprised of the circumstance, endeavoured to obtain a repetition of the effect, and found that the convulsions of the animal could be produced at pleasure, by drawing a spark from the prime conductor, at the time the scalpel was in contact with the nerve.

The novelty of the fact which he had thus been led to observe stimulated him to pursue with ardour the track which had been opened to his view. His experiments were accordingly numerous, and he developed many interesting facts, which he communicated to the public in a work published in 1791. He found that a prepared frog, that is, the hind legs of a frog with its crural nerves laid bare, constituted an electrometer of exquisite delicacy, being agitated by degrees of electricity far too minute to affect the best inorganic electrometer. An entire frog did not evince the same susceptibility, because its course was more extended. Electricity drawn from the atmosphere in the ordinary manner by means of a kite, produced the same effects on animals, according to its intensity, as that of the machine.

Accident soon assisted Galvani in his researches: having suspended some frogs from the iron palisades which surrounded his garden, by means of metallic hooks

fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily, as in the case above mentioned from electricity. He at first thought that these effects might be dependent on a particular state of the atmosphere; but this conjecture was refuted by the discovery that the same movements could be produced at any time, by touching the animals with two different metals, which at the same time touched one another, either immediately, or by the intervention of some other substance capable of conducting electricity. The contractions were stronger when a metallic coating such as tinfoil, was applied to the nerve.

Galvani supposed that the convulsions he had observed were produced by a disturbance of the electricity inherent in animals, which was identical with the nervous fluid, and that the metallic substances employed had not any other effect than that of transmitting the electricity from the muscles to the nerves, or from the nerves to the muscles, or two parts of the same muscle, provided two different metals were used. To explain the phenomena, he had recourse to the experiments of Bennet, who had some time before observed, that when plates of different metals were brought into contact, one of them transmitted a portion of its electricity to the other, and when separated, they evinced signs of opposite states of electricity. When the plates, for instance, were one of copper, and the other of zinc; the former, while the two were in contact, gave a portion of its electricity to the latter. Hence, when they were separated and examined by the electrometer, the copper exhibited signs of negative electricity, and the zinc those of positive. Volta therefore concluded, that the electricity evolved in the experiments in question, arose from the contact of the different metals, and the convulsions of the animals operated upon, were merely the consequences of the stimulus applied to their nerves and muscles, which were thus evinced to be most delicate electrometers.

The first stage or epoch in the history of galvanism, must be considered that in which it was observed that excited electricity produced muscular contractions in dead animals; the second, is that in which it was observed that different metallic bodies, by mere contact,

produced the same kind of contractions; the third, and most remarkable one, commences with Volta's admirable discovery of the means of accumulating the galvanic influence This invention, which justly confers so much celebrity on its author, is, in galvanism, analagous to that of the Leyden phial in common electricity, and became, like the phial, the precursor of the most brilliant discoveries; and philosophers can indeed as yet form but a very imperfect judgment of the consequences to which it will lead. It is called the Voltaic pile, and consists in combining the effects of a number of plates of different metals, by which means a galvanic battery, capable of giving a shock, is constituted. As silver and zinc had been found, when a single piece of each was employed, to have the greatest effect in producing muscular contractions, these metals were selected by Volta for his battery. The silver plates generally consisted of coins, and the plates of zinc were of the same size The like number of pieces of cloth, pasteboard, or leather, of the same size, and saturated with a solution of common salt were also provided. These substances were piled upon each other in the following order: first, zinc, then silver, then wet cloth; then again, zinc, silver, wet cloth, till by this regular alternation the pile became sufficiently high. If the height of the pile was considerable, it was usually supported by three pillars of glass or varnished wood. The pile thus formed, was found to unite the effects of as many pairs of plates as it contained. A pile of fifty pairs of plates, with as many corresponding pieces of wet cloth, was found to give a pretty smart shock, similar to an electric shock, every time that a communication was made between the top and bottom of the pile. It was found however, that little or no shock was perceived, when the hands, or other parts applied, were not previously moistened. It was also observed, that the effects were increased when a larger surface was exposed to the action of the pile. If the communication was made by touching the pile with the tip of each finger merely, the effect was not perceived beyond the joint of the knuckle; but if a spoon, or other metallic substance was grasped in moistened hands, the effect was felt up to the shoulder. If the communication be formed between any part of the face, particularly near the eyes, and

another part of the body, a vivid flash of light, corresponding with the shock is perceived. This phenomenon may be more faintly observed, by placing a piece of silver, as a shilling, between the upper lip and the gum, and laying a piece of zinc at the same time upon the tongue; upon bringing the two metals into contact, a faint flash of light generally appears. It is singular, that this light is equally vivid in the dark with the strongest light, and whether the eyes be shut or open.

Volta contrived another variety of the galvanic battery. The pairs of plates were soldered to each end of a bit of wire, which was afterwards bent into an arch, so that the plates became parallel to each other. Glass cups were then filled with a solution of common salt, and ranged side by side; the metallic arcs were so placed, that the silver plate was immersed in one cup, and the zinc plate in another; and each glass, except the extreme ones, contained one plate of each metal. Its effects are similar to those of the pile, when the circuit is completed by a communication between the liquid of the first and last glass.

The Voltaic pile, as well as the battery, are now but little used, having been superseded by batteries of more convenient form, particularly when a great accumulation of galvanism is required. In using the pile for example, it is tedious, after the cloth has become dry, to take the whole of the pile in pieces to moisten it, and the battery with glasses is deficient in compactness. Cruikshank, of Woolwich, therefore, invented a battery commonly called from its form, a galvanic trough. It consists of a trough of baked wood, about three inches deep, and three inches broad. The two sides of this vessel contain a number of perpendicular grooves, opposite each other, and about three-eighths of an inch apart. Into each pair of the grooves is put a plate of zinc and silver, or zinc and copper soldered together at the edges. These double plates are fastened in the grooves by means of a cement composed of five parts of rosin, four of bees' wax, and two of powdered red ochre. All the cells between the plates must be perfectly water tight, and care must therefore be taken to run in the cement so as to secure this point. It will be found convenient, and will facilitate the business of fixing the plates, if they be heated till

they can only just be handled, and smeared at the edges with the cement before they are put in. Any communication between the cells would destroy the effect.

The order of metals in a trough must be the same as in the pile, that is, the different metals must be next each other, and supposing zinc and copper to be used, if zinc be the outermost at one end, copper must be the outermost at the other.

The length of the trough is of course determined by the number of plates it is to contain, and the general rule is not to make the troughs heavier than one person can conveniently lift: fifty pairs of plates are a common number.

When the plates are properly fixed, the kind of fluid with which they are to be filled must be considered; water will answer only in a very slight degree; it has been found that the effect of the trough has been greatly increased by the use of liquids which are capable of oxidating, or exerting a chemical action on, at least, one of the metals; the water is, therefore, acidulated, or some common salt or muriate of ammonia is dissolved in it. Having filled the cells, the uppermost edges of the plates must be dried with a towel, to prevent any communication in that way.

When a communication is made between the first and the last cell, the same effects take place as when a communication is formed between the top and bottom of Volta's pile, only in degree proportioned to the difference of acting surface.

In performing experiments, the communication between the extremities of a battery is usually completed by inserting a wire at each end, and the extremities of these wires being brought nearly into contact, the galvanic action is exerted on any substance interposed between them, by which means very slender wires, or thin leaves of metals, or pieces of charcoal may be consumed; the action of galvanism upon inflammable bodies is astonishingly powerful, and the exhibition of it upon metals is particularly interesting.

When a great accumulation of galvanism is wanted it may be obtained by a combination of troughs. Pieces of copper bent so as to dip into the adjoining cells, connect the troughs together, and the wires connected with the ends, act on the substances with the accumulated force of

the whole number of troughs employed. In thus connecting batteries care must be taken that the zinc end of one trough be next to the copper end of the other.

GENERAL VIEW OF GALVANISM.

It has been much contested, whether galvanism and electricity are owing to the operations of the same fluid, but the question appears to be now satisfactorily decided in the affirmative. A principal argument in favour of their being different, was, that galvanism decomposed water, an effect of which electricity was not known to be capable. But Dr. Wollaston not only decomposed water by electricity, but produced, by the same agent, a variety of other effects, which had been previously considered as exclusively producible by galvanism. It appears, therefore, that the principal difference between electricity and galvanism consists in the mode of exciting, accumulating, and applying the fluid.

It will be proper to observe that the conductors of galvanism are divided into two classes: the first class includes dry and good conductors, such as metals and charcoal, the second class includes water and other oxidating fluids, and the substances which contain these fluids. This second class might be subdivided into species; for substances not themselves good conductors, if merely containing or moistened with a fluid, are not equal in conducting power to the fluid itself.

From the various researches of philosophers the following results have been obtained.

In common electricity, the fluid is excited by the rubbing of an electric or non-electric conductor, and without the electric no effect of this sort can be produced: in galvanism, the fluid is excited by the conductor alone, without the intervention of electrics, being evolved by the chemical agency of the substances employed; for Sir H. Davy discovered, that the electricity is produced by a chemical action of the different substances on each other, that the effect is greater or less in proportion as this

action is so, and that therefore two dissimilar metals are not essential to the evolutions of galvanism.

To produce the galvanic action, three different substances at least, which are conductors of electricity, must be placed in contact so as to form a circuit from one to another; for no sensible effect is produced from two conductors, nor from three when the communication between any two of them is broken by an electric; hence such a combination of three different conductors is called a simple galvanic circle.

It seems to be indispensably requisite, that in a simple galvanic circle, the conductor or conductors of one class should have some chemical action upon the other conductor or conductors; without which circumstance the combination of three bodies will have either no galvanic action at all, or a very slight one. Further, the galvanic action is evidently proportionate to the degree of chemical agency; which seems to show that some chemical action is the primary cause of the electric phenomena. The most active circles of the first order, are two solids of different degrees of oxidability and a fluid capable of oxidating at least one of the solids. Thus gold, silver, and water do not form an active galvanic circle; but the circle will become active, if a little nitric acid, or any fluid decomposable by silver is mixed with the water. A combination of zinc, silver and water forms an active galvanic circle, and the water is found to oxidate the zinc, provided the water holds some atmospherical air, and especially if it contains oxygen gas. But zinc, silver, and water containing a little nitric acid, form a more powerful galvanic circle, the fluid being capable of acting both upon the zinc and upon the silver. The most powerful galvanic combinations of the second order, are when two conductors of the second class have different chemical actions on the conductors of the first class, at the same time that they have an action on each other. Thus copper or silver, or lead, with a solution of an alkaline sulphuret, and diluted nitrous acid, forms a very active galvanic circle.

After Volta had discovered the pile, it became an interesting object of inquiry to ascertain, with as much minuteness as possible, the combinations of substances which produced the greatest effect. A vast number of

experiments were tried with this view by different persons, and at the Royal Institution, by which the following results were obtained.

Galvanic Circles of the first Order, viz., which consist of two Conductors of the First Class, and one of the Second.

Zinc with gold, or charcoal, or silver, or copper, or tin, or iron, or mercury; and water containing a small quantity of any of the mineral acids.

Iron, with gold, or charcoal, or silver, or copper, or tin, and a weak solution of any of the mineral acids, as above.

Tin, with gold, or silver, or charcoal and a weak solution of any of the mineral acids as above.

Lead, with gold, or silver, and a weak solution as above.

Any of the above metallic combinations and common water, viz., water containing atmospherical air, or especially water containing oxygen air.

Copper, with gold or silver, and a solution of nitrate of silver and mercury; or the nitric acid; or the acetous acid.

Silver, with gold and the nitric acid.

Galvanic Circles of the second Order, viz., which consist of one Conductor of the First Class, and two of the Second.

Charcoal, or Copper, or Silver, or Lead, or Tin, or Iron, or Zinc, with water, or with a solution of any hydrogenated alkaline sulphuret, capable of acting on the first three metals only; and diluted nitrous acid or oxygenated muriatic acid, &c., capable of acting upon all the metals.

The history of philosophy affords many examples of observations which have remained isolated and useless for ages, and which though often desired or discredited, have by the progress of discovery grown into importance, and become parts of a beautiful system; contributing at the same time essentially to the early maturity of some departments of knowledge. Hence those who have accurately detailed a single new phenomenon, which appeared to have no connexion with any thing useful or any thing known, have in fact often been performing a work which should give celebrity to their names, by the

direction it has given to inquiry, and the light it has thrown on subsequent researches.

In galvanism, several instances of the kind alluded to have occurred, and some of them it may be curious to mention.

A long time prior to the establishment of galvanism as a science, it had been observed, that if two different metals were placed in contact under water, they were subject to a rapid oxidation, though the water had no perceptible action upon them when they were alone.

It had also been observed that ancient inscriptions, made of mixed metals, were totally defaced; while those made of pure metals were in excellent preservation.

When metals have been soldered by means of other metals, they were found to tarnish about the places where they were joined; and the copper sheathing of ships, when fastened by means of iron nails, soon corrodes about the place where the different metals touch each other.

It had been generally affirmed that porter drunk out of a pewter vessel, has a taste different from that drunk out of a glass, or earthern ware.

It is now evident, that in all these cases, the metals produce these effects, by their galvanic action on each other.

The zinc end of a battery is considered to be plus, or positive; and the copper end to be minus, or negtive.

Galvanic batteries, containing an equal quantity of similar metallic surface, have different effects, if the size of the plates be different. The greater the number of the plates, the stronger is the shock which they will give; on the contrary, the larger the plates, the greater is their power of deflagration; the extent of surface in each case supposed to be the same.

Different animals are susceptible of galvanism in very different degrees. In cold blooded animals this susceptibility sometimes continues for several days after death; in the more perfect animals, as man, it continues only for a few hours, and sometimes ceases in a few minutes. A fish, with the organization of its head completely destroyed by bruises, preserves its irritability longer than if it had not been thus treated.

Frogs have been found the most convenient subjects

for galvanic operations. Galvani prepared these animals by skinning their legs when recently dead, and leaving the legs attached to a small part of the spine, but separated from the rest of the body. The strongest contractions are produced, when the galvanic electricity is caused to pass through the nerve to the muscles. Frogs, which have been galvanized very quickly become putrid.

Perhaps, most of those who try galvanic experiments merely for the purpose of amusement, would choose to dispense with the skinning of frogs. It may, therefore, be observed, that an ample proof of the power of galvanism over the dead animal muscle, may be obtained by galvanizing any animal killed for domestic use. It will only be necessary to point the wires from the battery, and to penetrate the skin with them, at the two parts between which a communication is intended to be made.

The medical uses of galvanism cannot yet be fully estimated. In some cases it has proved beneficial; in others, it has had no effect whatever; and in others, an unfavourable effect has been attributed to it. The cases in which it is in general most eligible to try it, are those for which common electricity is proper, and has failed. In instances of numbness, palsy, and suffocation, it has proved highly advantageous.

Various hypotheses have been offered to account for the phenomena of galvanism; but that which appears to be the most comprehensive, considers them as of an electrical nature. During the combination of a metal, and, perhaps, of other substances, with oxygen, a quantity of electricity it is supposed, is liberated or generated. In proof of the similarity of electricity and galvanism, Dr. Wollaston observes, that both appear to depend upon oxidation, for an amalgam not liable to oxidation, such as of gold and platina, will not excite an electrical machine, and the effect of any amalgam is in proportion to the ease with which it is oxidated.

To account for the difference in the effects between galvanism and electricity, it is asserted, and seems to be a well established fact, that galvanism is electricity in a state of little condensation. In proof of this, it is found that a common electrical jar or battery, may be charged by means of a galvanic battery; one wire from which,

for this purpose, must communicate with the inside, and the other, with the outside coating of the jar: the charge is given in a moment, but it is low, and such only as the jar would receive from a few turns of the ordinary electrical machine. Hence it is not difficult to explain, why the galvanic should be greatest from a numerous series of plates, while the largeness of the plates is most essential to deflagration; for the force of the electric shock depends upon the *intensity* of the electric fluid, while the combustion depends very much upon its *quantity*. If, then, six large pairs of plates, and six hundred small ones, contain the same surface, and produce equal quantities of the electric or galvanic fluid; yet, as in the latter series, the product is confined to narrow limits, and acquires probably a fresh impulse from every addition to its quantity in passing from plate to plate through its lengthened course, it arrives at the extremity of the apparatus in a state of much greater intensity then, when only a few plates are employed.

We shall make but one remark more: the galvanic investigations of Sir H. Davy tend to establish an opinion, that all substances which have a chemical action on each other, are in opposite electrical states, and that this difference of states, is the cause of such chemical action. Evidence is, however, wanting to confirm this beautiful hypothesis, and consequently it would be useless to show how it ought to modify chemical, galvanic, and electrical theories.

OPTICS.

The splendid phenomena of optics must have been among the first natural appearances to attract the attention of mankind. Of all the objects in nature, light is, perhaps, the most pleasurable. Vision, at once the most perfect and useful of the senses, wholly depends upon it. By its agency the sphere of our observation and experience is indefinitely enlarged. It brings sure and immediate intelligence of existences and events, whose places are remote, and thus gives us a certain degree of omnipresence. Setting aside all the beautiful variety and form of figure, and the gorgeous phenomena of colours, which it is the means of disclosing, light itself is a delightful perception. Nature supplies it so continually and so abundantly that we are apt to forget its value; but, in cases where habit has not blunted the sense of pleasure, it seems to produce singular enjoyment. The infant eagerly directs its gaze to the window or the lamp, and stretches forth its little hand as if to grasp an object so agreeable. Persons blind from infancy, but whose organs are not absolutely opaque, derive exquisite pleasure from the perception of the cloudy light which the imperfectly transparent humours allow them.

Optics, therefore, is one of the most interesting branches of Natural Philosophy: it is the science of vision, and teaches us how we see objects. In this science, bodies are divided into *luminous*, *opaque*, and *transparent*. A luminous body is one that shines by its own light—as the sun, the fire, a candle &c. But all bodies that shine are not luminous: polished metal, for example, when it shines with so much brilliancy, is not a luminous body, for it would be dark if it did not receive light from a luminous body; it belongs, therefore, to the class of opaque, or dark bodies, which comprehend all such as are neither luminous nor will admit the light to pass through them; and transparent bodies are those

which allow light to pass through them, such as glass and water. Transparent or pellucid bodies are frequently called mediums; and the rays of light which pass through them are said to be transmitted by them. Light when emitted from the sun, or any other luminous body, is projected forward in straight lines in every possible direction, or at least appears to move as it would on that supposition: so that the luminous body seems not only the general centre whence all the rays proceed, but every point may be considered as a centre which radiates light in every direction. A ray of light is a single line of light projected from a luminous body; and a pencil of rays is a collection of rays proceeding from one point of a luminous body.

Philosophers are not agreed as to the nature of light. Some maintain the opinion that it is a body consisting of detached particles, which are emitted by luminous bodies, in which case the particles of light must be inconceivably minute, since they must cross each other in every direction, they are never known to interfere with each other; others suppose it to be produced like sound by the undulations of a subtile fluid diffused throughout all known space. In some respects light is obedient to the laws which govern bodies; in others, it appears to be independent of them. Thus, though it corresponds with the laws of motion, it does not seem to be influenced by those of gravity; for it has never been discovered to have weight, though a variety of experiments have been made with a view of discovering that point. We are, however, so ignorant of the intimate nature of light, that an attempt to investigate it would lead us into a labyrinth of perplexity, if not of error. We shall therefore confine our attention to such of its properties as are well ascertained.

To return, then, to the examination of the effects of light from a luminous body; since the rays are projected in straight lines when they meet with an opaque body through which they are unable to pass, they are stopped short in their course for they cannot move in a curb line round the body. The interruption of the rays of light by the opaque body produces, therefore, darkness on the opposite side of it; and if this darkness fall upon a wall, a sheet of paper, or any object whatever, it forms a

shadow, for shadow is nothing more than darkness produced by the intervention of an opaque body. which prevents the rays of light from reaching an object behind it. You might suppose from this definition of a shadow, that it would be perfectly black; but it frequently happens that light from another body reaches the space where the shadow is formed, in which case the shadow is proportionably fainter. This happens if the opaque body be lighted by two candles, if you extinguish one of them, the shadow will be both deeper and more distinct. Yet it will not be perfectly dark, because it is still slightly illuminated by light reflected from the walls of the room and other surrounding objects.

There are several things to be observed in regard to the form and extent of shadows. If the luminous body be larger than the opaque body, the shadow will generally diminish in size till it terminate in a point; if smaller the shadow will continually increase in size, as it is more distant from the object which projects it. The shadow of a man varies in size according to the distance of the several surfaces on which it is described. Two lights produce two shadows from the same object. The number of lights (in different directions) while it decreases the intensity of the shadows, increases their number, which always correspond with that of the lights; for each light makes the opaque body cast a different shadow. Now what becomes of the rays of light which opaque bodies arrest in their course, and the interruption of which is the occasion of the shadows? This leads to a very important property of light—*Reflection.*

When rays of light encounter an opaque body which they cannot traverse, part of them are absorbed by it, and part are reflected, and rebound as an elastic-ball which is thrown against a wall. Light in its reflection is governed by the same laws as solid perfectly elastic bodies. If a ray of light fall perpendicular on an opaque body, it is reflected back in the same line towards the point whence it proceeded; if it fall obliquely, it is reflected obliquely; but in the opposite direction, the angle of incidence being equal to the angle of reflection. If the shutters be closed, and a ray of the sun's light admitted through a very small aperture, and reflected by a mirror on which the ray falls perpendicularly, but one

ray is seen; for the ray of incidence and that of reflection are both in the same line, though in opposite directions, and thus are confounded together. The ray, therefore, which appears single is in fact double, being composed of the incident ray proceeding to the mirror, and the reflected ray returning from the mirror. These may be separated by holding the mirror in such a manner that the incident ray shall fall obliquely upon it; then the reflected ray will go off in another direction. If a line be drawn from the point of incidence perpendicular to the mirror, it will divide the angle of incidence from the angle of reflection. and the angles will be equal.

It is by reflected rays only that we see opaque objects Luminous bodies send rays of light immediately to our eyes; but the rays which they send to other bodies are invisible to us, and are seen only when reflected or transmitted by those bodies to our eyes. Yet it may be observed that the ray of light on its passage from the sun to the mirror, and its reflection, have been spoken of as visible, though in neither case were those rays in a direction to enter our eyes. The fact is, that what is seen is the light reflected to the eye by small particles of dust floating in the air, and on which the ray shone in its passage to and from the mirror. So when, in common phrase, we speak of seeing the sun shining on an opposite house, it is impossible to see a single ray which passes from the sun to the house: no rays are visible but those which enter our eyes: therefore it is the rays which are reflected by the house, and not those which proceed from the sun to the house that are seen. Why, then, does one side of the house appear to be in sunshine, and the other in the shade? for if we cannot see the sun shine upon it, the whole of the house should appear in the shade. That side of the house on which the sun shines reflects more vivid and luminous rays than the side which is in shadow, the other being illuminated only by rays reflected upon by other objects: the rays therefore are twice reflected before they reach our sight; and as light is more or less absorbed by the bodies it strikes upon, every time a ray is reflected its intensity is diminished. Thus on a large sheet of water the sun appears to shine on one part only, though the whole of it is equally exposed to its rays. This partial brilliancy of

water is more remarkable by moonlight, on account of the deep obscurity of the surrounding parts. To account for this it must be remembered that the direction of a reflected ray depends on that of the incidence ray; the sun's rays therefore, which fall with various degrees of obliquity upon the water, are reflected in directions equally various, some of these will meet the eye, and it will see them, but those which fall elsewhere are invisible to it.

Let us now examine by what means the rays of light produce vision. They enter at the pupil of the eye, and proceeding to the retina or optic nerve, which is situated at the back of the eye ball, there describe the figure, colour, and (with the exception of size) form a complete representation of the object from which they proceed. If the shutters be closed, and a ray of light admitted through the small aperture, a picture may be seen on the opposite wall similar to that which is delineated on the retina of the eye; it exhibits a picture in miniature of the garden, and the landscape would be perfect were it not reversed. This picture is produced by the rays of light reflected from the various objects in the garden, and which are admitted through the hole in the window shutter. It is called a camera obscura (*dark chamber*), from the necessity of darkening the room in order to exhibit it.

The retina of the eye exhibits a much more perfect image than any mirror; the extensive landscape beheld from the window is there represented with the greatest accuracy. Art would in vain attempt to paint so small and distinct a miniature; but nature works with a surer hand and a more delicate pencil. That Power which forms the feathers of the butterfly and the flowerets of the daisy can alone pourtray so admirable and perfect a miniature. As the rays intersect each other on entering the pupil in the same manner as they do on entering the camera obscura the image is reversed. The scene however, does not excite the idea of being inverted, because we always see an object in the direction of the rays which it sends to us. How it is that we do so is a point rather difficult to explain clearly. The following, however, appears to be the best explanation:—A ray which comes from the upper part of an object describes the image on the lower part of the retina; but experience having

taught us that a ray which strikes the retina there comes from above, we consider that part of the object it represents as uppermost. The rays proceeding from the lower part of an object fall upon the upper part of the retina; but as we know their direction to be from below, we see that part of the object they describe as the lowest. When you wish to see an object above you, you look upwards; when an object below, you look downwards. You look up to see an elevated object, for it is only thus that the rays which proceed from it fall upon the retina of your eyes, and they must do so if you are to see the object; but the very circumstance of directing your eyes upwards convinces you that the object is elevated, and teaches you to consider as uppermost the image it forms on the retina, though it is in fact represented in the lowest part of it. When you look down on an object you draw your conclusion from a similar reasoning. It is thus that we see all objects in the direction of the rays which reach our eyes.

The different apparent dimensions of objects at different distances proceed from our seeing, not the objects themselves, but merely their image on the retina. Let us suppose we see a row of trees, as viewed in the camera obscura; the direction of the rays from the objects to the image is expressed by lines. Observe that the ray which comes from the top of the nearest tree, and that which comes from the foot of the same tree, meet at the aperture forming an angle of about twenty-five degrees; this is called the angle of vision, being that under which we see the tree. These rays cross each other at the aperture, and represent the tree inverted in the camera obscura. The dimensions of the image are considerably smaller than those of the object, but the proportions are perfectly preserved. The upper and lower ray, from the most distant tree form an angle of not more than twelve or fifteen degrees and an image of proportional dimensions. Thus the objects of the same size, as the two trees, form figures of different sizes in the camera obscura, according to their distance, or in other words, according to the angle of vision under which they are seen.

The experience we acquire by the sense of touch corrects the errors of our sight with regard to objects within our reach; we are so perfectly convinced of the real size of objects which we can handle, that we do not attend

to their apparent difference. The opposite house does not appear to you much smaller than if you was close to it; and yet you see the whole of it through one of the windows of the room you sit in, and the image of the house on your retina must be very considerably smaller than that of the window through which you see it. Those accustomed to draw from nature are well aware of this difference. When we look up an avenue, the trees not only appear smaller as they are more distant, but seem gradually to approach each other till they meet in a point, for the road which separates the two rows forms a smaller visual angle, in proportion as it is more distant from us; therefore the width of the road seems gradually to diminish as well as the size of the trees, till at length the road apparently terminates in a point at which the trees seem to meet.

In sculpture we copy Nature as she really exists; in painting we represent her as she appears to us, that is to say, we do not copy the objects, but the image they form on the retina of the eye.

If an object with an ordinary degree of illumination does not subtend an angle of more than half a minute of a degree, it is invisible. There are, consequently, two cases in which objects may be invisible, either if they are too small, or so distant as to form an angle less than one second of a degree. The fixed stars subtend much smaller angles, and yet are visible; but they are bodies luminous in themselves, and possess much more than any ordinary degree of illumination. In like manner, if the velocity of a body be so small that the arc which it describes in an hour does not subtend an angle of more than twenty degrees, its motion is imperceptible, provided the distance of the moving body be sufficiently great; for the greater its distance, the smaller will be the angle under which its motion will appear to the eye. It is for this reason that the motion of the celestial bodies is invisible notwithstanding their immense velocity; for the greatest *apparent* motion of any celestial body does dot exceed fifteen degrees in an hour, being that seemingly produced in a body at the equator by the revolution of the earth. The greatest of the real motions is that of the moon, and even that does not exceed above thirteen degrees in a

day. The real velocity depends altogether on the space comprehended in each degree; and this space depends on the distance of the object, and the obliquity of its path. Light cannot be implicitly relied on; it deceives us both in regard to the size and distance of objects—indeed our senses would be very liable to lead us into error, if experience did not set us right. Nothing more convincingly shows how requisite experience is to correct the errors of sight tham the case of a young man who was blind from his infancy, and who recovered his sight at the age of fourteen, by the operation of couching. At first he had no idea either of the size or distance of objects, but imagined that every thing he saw touched his eyes, and it was not till after having repeatedly felt them, and walked from one object to another, that he acquired an idea of their respective dimensions, their relative situations, and their distances.

Since an image is formed on the retina of each of our eyes, it would seem that we ought to see objects double. In fact, however, we do not; and perhaps the best solution which has been offered of the difficulty is this, that the action of the rays on the optic nerve of each eye is so perfectly similar, that they produce but a single sensation: the mind, therefore, receives the same idea from the retina of both eyes, and conceives the object to be single. It is however, more safe to treat the fact as one established by experience, but not admitting of any satisfactory explanation; for the manner in which external objects act upon the mind admits of no direct observation, and all theories respecting it can therefore rest on no sound foundation. Persons afflicted with a disease in one eye, which prevents the rays of light from affecting it in the same manner as the other, frequently see double.

The image of an object in a looking-glass is not inverted, because the rays do not enter the mirror by a small aperture, and cross each other as they do at the orifice of a camera obscura, or the pupil of the eye.

When a man views himself in a mirror, the rays from his eyes fall perpendicularly upon it, and are reflected in the same line; they proceed therefore, as if they had come from a point behind the glass, and the same effect is produced, as if they proceeded from an image of the object described behind the glass, and situated there in

the same manner as the object before it. This is not the case only with respect to rays falling perpendicularly on the glass, but with all others.

A man may see himself at full length in a mirror which is not more than half his height; but he cannot see himself if he stand to the right or the left of it, because the incident rays falling obliquely on the mirror will be reflected obliquely in the opposite direction; the angles of incidence and reflection being equal.

But we must observe, that in a glass mirror it is not the glass that reflects the rays which form the image, but the mercury behind it. The glass acts chiefly as a transparent case, through which the rays find an easy passage. Could mirrors be made of mercury, they would reflect more perfectly; but mercury is a fluid. By amalgamating with tin-foil, it becomes of the consistence of paste, attaches itself to the glass, and forms, in fact, a mercurial mirror, which would be much more perfect without its glass cover, for the purest glass is never completely transparent: some of the rays, therefore, are lost during their passage through it, by being absorbed, or irregularly reflected. This imperfection of glass mirrors has introduced the use of metallic mirrors for optical purposes. All opaque bodies would be mirrors, were their surfaces sufficiently smooth; but the surface of bodies in general is so rough and uneven, that their reflection is extremely irregular, which prevents the rays from forming an image on the retina. You may easily conceive the variety of directions in which rays would be reflected by a nutmeg-grater on account of the inequality of its surface, and the number of holes with which it is pierced. Now all solid bodies resemble the nutmeg-grater in these respects more or less; and it is only those which are susceptible of receiving a polish, that can be made to reflect the rays with regularity. As hard bodies are of the closest texture, the least porous, and capable of taking the highest polish, they make the best mirrors; none therefore are so well calculated for this purpose as metal.

There are three kinds of mirrors used in optics: the *plane* or *flat*, which are the common mirrors we have just noticed, *convex mirrors*, and *concave mirrors*. The reflection of the two latter are very different from the former.

The *plane mirror*, we have seen, does not alter the direction of the reflected rays, and forms an image behind the glass exactly similar to the object before it: for it forms an image of each point of the object at the same distance behind the mirror, that the point is before it: and these images of the different points together make up one image of the whole object. A convex mirror has the peculiar property of making the reflected rays diverge, by which means it diminishes the image, and a concave mirror makes the rays converge, and, under certain circumstances, magnifies the image. Let us begin by examining the reflection of a convex mirror. This is formed of a portion of the exterior surface of a sphere. When several parallel rays fall upon it, that ray only which, if prolonged, would pass through the centre or axis of the mirror, is perpendicular to it. If the rays diverge before they fall on the mirror, they will diverge still more after reflection, but in this case also they will diverge as if they proceed from a point within the mirror, which is the focus of those rays. The rays, therefore, which really proceed from a point of the mirror, will appear to proceed from a point within it, at which they would unite, and form an image. This point within the mirror, like the imaginary focus of parallel rays, is always a point in the line joining the centre of the sphere, with the point without the mirror, from which the rays really proceed.

If instead of supposing a single luminous point, we imagine a body of some magnitude placed before the mirror, the rays of light which proceed from each point of it will be reflected exactly in the same manner as if that was a single luminous point; and an image of that point therefore will be formed as before, in the line joining that point to the centre of the sphere. An image being thus formed of each point in the object, there will be an image of the whole object, formed by the collection of these images in its different parts.

A *concave mirror* is formed of a portion of the internal surface of a hollow sphere, and its peculiar property is to make the rays of light converge. If three parallel rays fall on the concave mirror, the middle ray will be reflected in the same line, being in the direction of the axis of the mirror, and the two others will be reflected obliquely, as they fall obliquely on the mirror. When any number

of parallel rays fall on a concave mirror they are all reflected to a focus: for in proportion as the rays are more distant from the axis of the mirror, they fall more obliquely upon it, and are more obliquely reflected: in consequence of which they come to a focus in the direction of the axis of the mirror; and this point is not an imaginary focus (as with the convex mirror), but the true focus at which the rays unite. If rays fall convergent on a concave mirror, they are sooner brought to a focus than parallel rays; but the true focus of mirrors, either convex or concave, is that formed by parallel rays, which is equally distant from the centre and the surface of the sphere. If a metalic concave mirror of polished tin be exposed to the sun, the rays will be collected into a very brilliant focus, and a piece of paper held in this focus will take fire; for rays of light cannot be concentrated without accumulating a proportionate quantity of heat; hence concave mirrors have obtained the name of burning mirrors. If a burning candle be placed in the focus, the ray which falls in the direction of the axis of the mirror will be reflected back in the same line; but two other rays drawn from the focus and falling on the mirror will be also reflected. Therefore the rays which proceed from a light placed in the focus of a concave mirror fall divergent upon it, and are reflected parallel; it is exactly the reverse of the former figure, in which the sun's rays fell parallel on the mirror, and were reflected to a focus. In other words when the incident rays are parallel, the reflected rays converge to a focus; when the incident proceed from the focus, they are reflected parallel; this is a very important law of optics. We have said that the image was formed in the focus of a concave mirror, yet glass concave mirrors are often seen, where the object is represented within the mirror, in the same manner as in those which are convex. This is the case only when the object is placed between the mirror and its focus; the image then appears magnified behind, or within the mirror.

REFRACTION AND COLOURS.

Refraction is the effect which transparent mediums produce on light in its passage through them. Opaque bodies reflect the rays, and transparent bodies transmit them; but it is found, that if a ray in passing from one medium into another of different density, fall obliquely, it is turned out of its course. The power which causes the deviation of the ray is not fully understood, nor completely ascertained; but the appearances are the same as if the ray (supposing it to be a succession of moving particles, which is for this purpose the most convenient way of considering it) were attracted by the denser medium more strongly than by the rarer. Let us suppose the two mediums to be air and water: when a ray of light passes from air into water, it appears to be more strongly attracted by the latter. If then a ray fall perpendicularly on water, the attraction of the water acts in the same direction as the course of the ray; it will not, therefore, cause a deviation, and the ray will proceed straight on; but if it fall obliquely, the water will attract it out of its course. Let us suppose the ray to have reached the surface of a denser medium, and that it is there affected by its attraction. If not counteracted by some other power, this attraction would draw it perpendicularly to the water; but it is also impelled by its projectile force, which the attraction of the denser medium cannot overcome: the ray, therefore, acted on by both these powers, moves in a direction between them, and instead of pursuing its original course, or being implicitly guided by the water, it appears bent or broken. Let us suppose a ray passing obliquely from glass into water; glass being the denser medium, the ray will be more attracted by that which it leaves, than by that which it enters; so that when a ray passes from a dense into a rare medium, a refraction takes place in the opposite direction to that observed when the ray passes from a rare into a dense medium. The distance at which the denser medium produces its effect upon a ray is so small as to be insensible: the ray appears, therefore, to be refracted only at the

point at which it passes from one medium to the other, and passes on in a straight course through each.

If a shilling be placed at the bottom of an empty basin, and the basin at such a distance from the eye, that the rim shall hide the shilling, it will become visible, by filling the basin with water. In the first instance, the rays reflected by the shilling, are directed higher than the eye; but when the basin is filled with water, they are refracted by its attraction, and bent downwards at quitting it, so as to enter the eye. When the shilling becomes visible, by the refraction of the ray, you do not see it in the situation which it really occupies, but an image of it higher in the basin; for, as objects always appear to be situated in the direction of the rays which enter the eye, the shilling will be seen in the direction of the refracted ray.

The manner which an oar appears bent in water is a similar effect of refraction. Every point of the oar below the surface of the water, will have an image of itself formed above it at some point. The part of the oar above the water, is seen in its natural position; that below the water, appears broken or bent, at the surface of the water. The fact of the formation of an image above the true place of the body, does not depend on the situation of the eye.

When we see the bottom of a clear stream, the rays which it reflects, being refracted in their passage from the water into the air, will make the bottom appear more elevated than it really is, and the water will consequently appear more shallow. Serious accidents have frequently been occasioned by this deceptive circumstance; and boys, who are ignorant of this fact, in the habit of bathing, should be cautioned, not to trust to the apparent shallowness of the water, as it will always prove deeper than it appears.

The refraction of light prevents our seeing the heavenly bodies in their real situation. The light they send to us being refracted in passing into the atmosphere, we see the sun and stars in the direction of the refracted ray. If the sun was immediately over our heads, its rays falling perpendicularly on the atmosphere would not be refracted, and we should then see it in its true situation. To the inhabitants of the torrid zone, where the

sun is sometimes vertical, its rays are not then refracted. There is, however, another obstacle to seeing the heavenly bodies in their true situation, which affects them in the torrid zone, as elsewhere. Light is about eight minutes and a half in its passage from the sun to the earth; therefore, when the rays reach us, the sun has quitted the spot he occupied on their departure; yet we see him in the direction of those rays, and consequently in a situation which he had abandoned eight minutes and a half before. In speaking of the sun's motion, we mean his apparent motion, produced by the diurnal rotation of the earth, for the effect being the same, whether it be our earth, or the heavenly bodies which move, it is more easy to represent things as they appear to be, than as they really are. The refraction of the sun's rays by the atmosphere prolongs our days, as it occasions our seeing an image of the sun, both before he rises, and after he sets; for below the horizon he still shines upon the atmosphere, and his rays are thence refracted to the earth. So likewise, we see an image of the sun before he rises, the rays that previously fell upon the atmosphere being reflected to the earth.

In passing through a pane of glass the rays suffer two refractions, which being in contrary directions, produce nearly the same effect as if no refraction had taken place.

Lenses.—The focal distance, or distance of the focus from the surface of the lens, depends both upon the form of the lens and of the refractive power of the substance of which it is made; in a glass lens, both sides of which are equally convex, the focus is situated nearly at the centre of the sphere of which the surface of the lens forms a portion: it is at the distance, therefore of the radius of the sphere.

There are lenses of various forms. The property of those which have a convex surface is to collect the rays of light to a focus; and those which have a concave surface, to disperse them. Lenses which have one side flat, and the other convex or concave, are called plano-convex and plano-concave. The focus of the former is at the distance of the diameter of a sphere of which the convex surface of the lens forms a portion. Parallel rays are brought to a focus by the plano-convex lens at a point.

Thus far we have only spoken of the refraction of

parallel rays; if rays diverge originally, they will be less convergent or more divergent after refraction, but they would in general still finally meet at a point, or appear to diverge from one. Taking the case of a convex lens, the point at which they would meet would be farther from the lens than that in which parallel rays meet, and continually farther and farther, as the rays were more divergent, or as the body from which they proceeded was brought nearer to the lens. An image would therefore be formed, but continually farther and farther from the lens as the body approached it: and the image is smaller or larger than the body, as it is nearer to or farther from the lens than the body itself is. If the body is brought as near to the lens as the distance of the focus for parallel rays, no image would be formed, for the rays would be refracted parallel to each other; and if the body were brought still nearer, the rays would diverge after refraction. The case of a convex lens is one of the most simple and the most important; but the same principle may easily be extended to other cases.

We shall next direct our attention to the refraction of a triangular piece of glass, called a prism. The sides are flat; it cannot bring the rays to a focus, nor can its refraction be similar to that of a flat pane of glass, because it has not two sides parallel. The refractions of the light, on entering and on quitting the prism, are both in the same direction. If the window shutters be closed, and a ray of light admitted through a small aperture, fall upon a prism, it will be refracted; and a spectrum representing all the colours of the rainbow, will be formed on the opposite wall. It is difficult to conceive how a piece of white glass can produce such a variety of brilliant colours; but the fact is, that the colours are not formed by the prism, but existed in the ray previous to its refraction; for the white rays of the sun are composed of coloured rays, which when blended together, appear colourless or white.

Sir Isaac Newton to whom we are indebted for the most important discoveries respecting light and colours, was the first who divided a white ray of light, and found it to consist of an assemblage of coloured rays which formed an image on the wall, displaying the following colours—red, orange, yellow, green, blue, indigo, and violet. Now

a prism separates these coloured rays by refraction. We pointed out the method adopted by Newton in making this experiment in a previous portion of this work. It appears that the coloured rays have different degrees of refrangibility; in passing through the prism, therefore, they take different directions, according to their susceptibility of refraction. The violet rays deviate most from their original course: they appear at one end of the spectrum. Contiguous to the violet are the indigo rays, being those which have somewhat less refrangibility: then follow, in succession, the blue, green, yellow, orange, and, lastly, the red, which are the least refrangible of the coloured rays. The union of these colours, in the proportions in which they appear in the spectrum, produces in us the idea of whiteness. If a card be painted in compartments, with the seven colours, and whirled rapidly on a pin, it will appear white. But a more decisive proof of the composition of a white ray is afforded by reuniting these coloured rays, and forming with them a ray of white light. This can be done by letting the coloured rays, which have been separated by a prism, fall upon a lens, which will make them converge to a focus; and when thus reunited, they will appear white as they did before refraction. The prism separates a ray of white light into seven coloured rays; and the lens brings them to a focus, where they again appear white: thus by means of a prism and a lens, we can take a ray of white light to pieces, and put it together again.

This division of a ray of white light into different colours, being caused by the unequal refrangibility of the different coloured rays, must take place, more or less, whenever the ray suffers refraction. Thus the rainbow, which exhibits a series of colours so analogous to those of the spectrum, is formed by the refraction of the sun's rays in their passage through a shower of rain; every drop of which acts as a prism, in separating the coloured rays as they pass through it.

The sun's rays may be collected to a focus by a lens in the same manner as they are by a concave mirror: in the first, the rays pass through the glass and converge to a focus behind it; in the latter they are reflected from the mirror, and brought to a focus before it. A lens, when

used for this purpose, is called a burning-glass; and if, when the sun shines bright, a piece of paper be held in the focus of the rays it will take fire. This experiment succeeds best with brown or any dark coloured paper; for though it is true that the lens collects an equal number of rays to a focus, whether the paper held there be white or coloured, the white paper appears more luminous in the focus, because most of the rays, instead of entering into the paper, are reflected by it, and this is the reason that the paper is not burnt; whilst, on the contrary, the coloured paper which absorbs more light than it reflects, soon becomes heated and takes fire.

It is supposed that the tendency to absorb or reflect rays depends on the arrangement of the minute particles of the body, and that the diversity of arrangement renders same bodies susceptible of reflecting one coloured ray, and absorbing the others; whilst other bodies have a tendency to reflect all the colours, and others again to absorb them all. A body appears to be of the colour which it reflects; as we see it only by reflected rays, it can but appear of the colour of those rays. Thus grass is green, because it absorbs all but the green rays: it is therefore these only which the grass and leaves of trees reflect to our eyes, and which make them appear green, The sky and flowers in the same manner reflect the various colours of which they appear to us: the rose the red rays; the violet the blue; the jonquil the yellow, &c. If you imagine that these are the permanent colours of the grass and flowers, you are mistaken. Whenever you see those colours, the objects must be illuminated; and light, from whatever source it proceeds, is of the same nature, composed of the various coloured rays, which paint the grass, the flowers, and every coloured object in nature. Objects in the dark have no colour, or are black, which is the same thing. You can never see objects without light. Light is composed of colours, therefore there can be no light without colours; and though every object is black, or without colour in the dark, it becomes coloured as soon as it becomes visibel.

An object placed in a coloured ray of light which has been refracted by a prism, will appear of the colour of the ray in which it is placed. A sheet of white paper will take all the colours indifferently, but a coloured body will

appear most brilliant when placed in the ray which it naturally reflects. But though bodies, from the arrangement of their particles, have a tendency to absorb some rays and reflect others, yet they are not so perfectly uniform in the arrangement as to reflect only pure rays of one colour, and perfectly to absorb the others. A body reflects, in great abundance, the rays which determine its colour, and the others in a greater or lesser degree, in proportion as they are nearer or farther from its own colour, in the order of refrangibility.

Bodies which reflect all the rays are white; those which absorb them all are black. Between these extremes they appear lighter or darker in proportion to the quantity of rays they absorb or reflect. A rose is of a pale red; it approaches nearer to white than to black; it therefore reflects rays more abundantly than it absorbs them. Pale-coloured bodies reflect all the coloured rays to a certain degree, which produces their paleness, approaching to whiteness; but one colour they reflect more than the rest: this predominates over the white, and determines the colour of the body. Since, then, bodies of a pale colour in some degree reflect all the rays of light, in passing through the various colours of the spectrum, they will reflect them all with tolerable brilliancy, but will appear most vivid in the ray of their natural colour. The green leaves, on the contrary, are of a dark colour, bearing a stronger resemblance to black than to white: they have, therefore, a greater tendency to absorb than to reflect rays. Blue often appears green by candle-light, because this light is less pure than that of the sun, and when reflected by a prism, the yellow rays predominate; and as the admixture of blue and yellow forms green, the superabundance of yellow gives to blue bodies a greenish hue.

The sun appears red through a fog, owing to the red rays having a greater momentum, which gives them power to traverse so dense an atmosphere. For the same reason, the sun generally appears red at rising and setting; as the increased quantity of atmosphere which the oblique rays must traverse, loaded with the mists and vapours, which are usually formed at those times, prevents a large proportion of the other rays from reaching us. The colour of the atmosphere, commonly called the

sky, is blue;—now since all the rays traverse it in their passage to the earth, it would be natural to infer that it should be white; but we must not forget that we see none of the rays which pass from the sun to the earth, excepting those which meet our eyes; and this happens only if we look at the sun, and thus intercept the rays, in which case you know it appears white. The atmosphere is a transparent medium, through which the sun's rays pass freely to the earth; but when reflected back into the atmosphere, their momentum is considerably diminished, and they have not all of them power to traverse it a second time. The momentum of the blue rays is least; these, therefore, are the most impeded in their return, and are chiefly reflected by the atmosphere; or it may be, that without any question of momentum, the colour which the particles of air most readily reflect is blue—just as grass reflects the green, or a rose the red rays. This reflection is performed in every possible direction; so that wherever we look at the atmosphere, some of these rays fall upon our eyes; hence we see the air of a blue colour. If the colour of the atmosphere did not reflect any rays, though the objects on the surface of the earth would be illumined, the skies would appear perfectly black. This would not only be very melancholy, but pernicious to the sight, to be constantly viewing light objects against a black sky.

When bodies change their colour, as leaves which wither in autumn; or a spot of ink, which produces an iron mould on linen, it arises from some chemical change, which takes place in the internal arrangement of the parts, by which they lose their tendency to reflect certain colours, and acquire the power of reflecting others. A withered leaf thus no longer reflects the blue rays: it appears, therefore, yellow, or has a slight tendency to reflect several rays which produce a dingy brown colour. An ink-spot on linen at first absorbs all the rays; but, exposed to the air, it undergoes a chemical change, and the spot partially regains its tendency to reflect colours, but with a preference to reflect the yellow rays; and such is the colour of the iron mould.

THE STRUCTURE OF THE EYE.

The body of the eye is of a spherical form. It has two membraneous coverings;—the external one is called the sclerotica: this has a projection in that part of the eye which is exposed to view, which is called the cornea; because, when dried. it has nearly the consistence of very fine horn, and is sufficiently transparent for the light to obtain free passage through it. The second membrane which lines the cornea, and envelopes the eye is called the choroid; this has an opening in front just beneath the cornea which forms the pupil, through which the rays of light pass into the eye. The pupil is surrounded by a coloured body of fibres, called the iris, which, by its motion always preserves the pupil of a circular form, whether it be expanded in the dark, or contracted by a strong light.

The construction of the eye is so admirable, that it is capable of adapting itself, more or less, to the circumstances in which it is placed. In a faint light, the pupil dilates so as to receive an additional quantity of rays; and in a strong light it contracts, in order to prevent the intensity of the light from injuring the optic nerve. The eyes suffer pain, when from darkness they come suddenly into a strong light; for the pupil being dilated, a quantity of rays rush in before it has time to contract; and when we go from a strong light into obscurity, we at first imagine ourselves in total darkness; for a sufficient number of rays cannot gain admittance into the contracted pupil to enable us to distinguish objects; but in a few minutes it dilates, and we clearly perceive what was before invisible. The choroid is imbued with a black liquor, which serves to absorb all the rays that are irregularly reflected, and to convert the body of the eye into a more perfect camera obscura. When the pupil is expanded to its utmost extent, it is capable of admitting ten times the quantity of light that it does when most contracted. In cats and animals which are said to see in the dark, the power of dilatation and contraction of the pupil is still greater: it is computed that their pupils may receive one

hundred times more light at one time than at another. Within these coverings of the eyeball are contained three transparent substances called humours. The first occupies the space immediately behind the cornea and is called the aqueous humour, from its liquidity and resemblance to water. Beyond this is situated the crystaline humour, which derives its name from its clearness and transparency: it has the form of a lens, and refracts the rays of light in a greater degree of perfection than any that have been constructed by art: it is attached by fibres to each side of the choroid. The back part of the eye, between the crystaline humour and the retina, is filled by the vitreous humour, which derives its name from a resemblance it is supposed to bear to glass or vitrified substances. The membranous coverings of the eye are intended chiefly for the preservation of the retina, which is by far the most important part of the eye, as it is that which receives the impression of the objects of sight. The retina consists of an expansion of the optic nerve of perfect whiteness: it proceeds from the brain, enters the eye on the side next the nose, and is finely spread over the interior surface of the choroid. The rays of light which enter the eye by the pupil, are refracted by the several humours in their passage through them, and unite in a focus on the retina.

Rays proceed from bodies in all possible directions; we must therefore consider every part of an object which sends rays to our eyes as points from which the rays diverge, as from a centre. Divergent rays, on entering the pupil, do not cross each other; the pupil, however, is sufficiently large to admit a small pencil of them; and these, if not refracted to a focus by the humours, would continue diverging after they had passed the pupil, would fall dispersed upon the retina, and thus the image of a single point would be expanded over a large portion of the retina. The divergent rays from every other point of the object would be spread over a similar extent of space, and would interfere and be confounded with the first, so that no distinct image could be formed on the retina.

Let us suppose two pencils of rays issuing from two points of a tree, and entering the pupil, refracted by the crystalline humour, and forming distinct images of the

spot they proceed from on the retina; but if the eye was not supplied with a lens, the pencils of rays could not be refracted, and no distinct image formed on the retina. The rays issuing from two points would alone be delineated. The interference of these two pencils of rays enables us to form an idea of the confusion which would arise from thousands and millions of points, at the same instant, pouring their divergent rays upon the retina. The refraction of the several humours unites the whole of a pencil of rays proceeding from any one point of an object, in a corresponding point on the retina, and the image is thus rendered distinct and strong. You may, perhaps, inquire why, since the eye requires refracting humours in order to form a distinct representation on the retina, the same refractions are not necessary for the image formed in the camera obscura? It is because the aperture through which we receive the rays into the camera obscura is so extremely small, that but very few of the rays diverging from a point gain admittance; but if the aperture be enlarged, and furnished with a lens, the landscape will be more perfectly represented.

That imperfection of sight which arises from the eyes being too prominent, is owing to the crystaline humour being too convex; in consequence of which it refracts the rays too much, and collects a pencil proceeding from the object into a focus before they reach the retina. From this focus the rays proceed diverging, and consequently form a very confused image on the retina. This is the defect of short-sighted people; and it is remedied by bringing the object nearer to the eye; for the nearer an object is brought to the eye the more divergent the rays fall upon the crystaline humour, and therefore do not so soon converge to a focus: this focus, therefore, either falls upon the retina, or at least approaches nearer to it, and the object is proportionally distinct. The nearer, therefore, an object is brought to a crystaline or to a lens, the further the images recede behind it. But short-sighted persons have another resource for objects which they cannot approach to their eyes: this is to place a concave lens before the eye, in order to increase the divergence of the rays, the effect of a concave lens being exactly the reverse of a convex one. By the assistance of such glasses, therefore, the rays from a distant object

fall on the pupil as divergent as those from a less distant object; and, with short-sighted people, they throw the image of a distant object back as far as the retina. Those who suffer from the crystaline humour being too flat, apply an opposite remedy: that is to say, a convex lens to make up for the deficiency of convexity of the crystaline humour. Thus elderly people, the humours of whose eyes are decayed by age, are under the necessity of using convex spectacles; and when deprived of that resource, they hold the object at a distance from their eyes, for the more distant the object is from the crystaline, the nearer the image will be to it. These two opposite defects are easily comprehended; but it is difficult to conceive how any sight can be perfect, for if the crystaline humour be of a proper degree of convexity to bring the image of distant objects to a focus on the retina, it will not represent near objects distinctly; and if, on the contrary it be adapted to give a clear image of near objects, it will produce a very imperfect one of distant objects. It is true, that every person would be subject to one of these two defects, were it not in our power to increase or diminish, in some degree, the convexity of the crystaline humour, and to project it towards, or draw it back from the object, as circumstances require. In a young well-constructed eye the fibres to which the crystaline humour is attached have so perfect a command over it, that the focus of the rays constantly falls on the retina, and an image is formed equally distinct both of distant objects and those which are near. We cannot, however, see an object distinctly, if we bring it very near to the eye, because the rays fall on the crystaline humour too divergent to be refracted to a focus on the retina. The confusion therefore arising from viewing an object too near the eye is similar to that which proceeds from a flattened crystaline humour; the rays reach the retina before they are collected to a focus. If it were not for this imperfection, we should be able to see and distinguish the parts of objects which are now invisible to us from their minuteness; for could we bring them close to the eye, their image on the retina would be so much magnified as to render them visible.

The microscope is constructed on this principle. The single microscope consists simply of a convex lens, in the

focus of which the object is placed, and through which it is viewed. By this means you are enabled to bring your eye very near the object, for the lens, by diminishing the divergency of the rays before they enter on the pupil, makes them full parallel on the crystaline humour, by which they are refracted to a focus on the retina. The lens magnifies the object merely by allowing us to bring it nearer to the eye; those lenses, therefore, which have the shortest focus is most convex; and its protuberance will prevent the eye from approaching very near the object. This inconvenience is remedied by making the lens extremely small; it may then be spherical without occupying much space, and thus unite the advantages of a short focus, and of allowing the eye to approach the object.

A double microscope is a more complicated instrument, in which you look not directly at the object, but at a magnified image of it. In this microscope two lenses are employed: the one is placed so near the object, that the image which it forms is farther from the lens than the object itself is; the image, therefore, is larger than the object itself, and it is further magnified by being viewed through another lens, which acts on the principle of the single microscope, and is called the eye-glass. The solar microscope is the most wonderful, from its great magnifying power: in this we also view an image formed by a lens, not the object itself. A ray of light if admitted into a darkened room, through a small aperture in the window-shutter, and the object placed before the lens, and nearly at its focus; the lens itself being placed at such a distance from the opposite wall, that an image may be accurately formed upon it; the image, therefore, will be represented on the opposite wall in the same manner as the landscape was in the camera obscura—with this difference, that it will be magnified instead of being diminished, because it is further from the lens than the object; while the representation of the landscape was diminished, because it was nearer the lens than the landscape was: a lens, therefore, answers the purpose equally well, either for magnifying or diminishing objects. There is but one thing more required to complete the solar microscope, which is a small mirror placed on the outside of the window, which receives the incident rays and

reflects them on the lens. This microscope can only be used when the sun shines, and is adapted to transparent objects.

OPTICAL INSTRUMENTS.

The construction of optical instruments has, in almost every instance, originated with eminent philosophers and mathematicians. Their gradual perfection has been a natural result of the difficulties which were presented to the progress of discovery, by the inefficient and inaccurate means which science possessed; and thus, the same great minds have struck out and pursued vast and splendid ideas in their investigations of nature, have only been enabled to follow up their own conceptions by applying themselves to the practical improvement of the instruments with which they had commenced their discoveries. For example, we are indebted to Newton for the construction of the first reflecting telescope that was ever made, although the idea had been previously suggested by Doctor Gregory. Leuwenhoek, one of the most assiduous naturalists of his day, carried on his interesting researches in the animal and vegetable economy, by means of microscopes made by his own hands. The late Doctor Herschel, whose astronomical discoveries were the result of the profoundest mathematical knowledge, constructed the most powerful telescopes ever known, which, like the Gregorian, bear the name of the inventor. Indeed the ordinary makers of optical instruments have been often men of considerable scientific attainments;—and it is from this union of a theoretical and practical knowledge, that these instruments, as is the case with almost every other important invention and improvement, have been conducted to their present very high state of perfection, in an almost unlimited adaptation to the purposes of science, and all the wants and luxuries of common life.

The ancients seem to have been but little acquainted with dioptrical instruments, or those by which the light is refracted and transmitted; from their earliest history,

however, they appear to have been conversant with the laws of the reflection of objects from the surface of water and polished metals, or that department of optical science called catoptrics. The first application of their knowledge of this branch of science, with which we are acquainted, is that of the burning mirrors of Archimedes, a philosopher of Syracuse, about two hundred years before the birth of Christ, who, at the siege of that city, by Marcellus, the Roman consul, employed them to destroy the besieging navy. The method by which this was probably accomplished is thus described by an ancient historian:—"When the fleet of Marcellus was within bowshot, the old man, Archimedes, brought out an hexagonal mirror, which he had previously prepared, at a proper distance from which he also placed other smaller mirrors of the same kind, that moved in all directions on hinges, which, when placed in the sun's rays, directed them upon the Roman fleet, whereby it was reduced to ashes." We are also informed, that Proclus in the same way destroyed the fleet of Vitellius, at the siege of Byzantium.

In this limited notice, we will be only able to point out a few of the more remarkable peculiarities of optical instruments.

Mirrors are surfaces of polished metal, or glass silvered on the back, capable of reflecting the rays of light from objects placed before them, and exhibiting to us their image. As we have previously remarked, there are three classes of mirrors, distinguishable by the figure of their reflecting surface—*plane*, *concave*, and *convex*. The reflection of light by either of these mirrors observes this constant *law*, that the angle which the incident ray makes with the reflecting surface, is equal to the angle of reflection. As already stated, the image appears behind the glass, exactly at the same distance as the object is before it. The illusion is so complete, that domestic animals, when seeing themselves in a looking-glass for the first time, often have their passions strongly excited. When a person is viewing himself in a looking-glass, if he measures the size which he appears on the glass, the image will be one half his real magnitude, let his distance from the glass be ever so varied.

Concave Mirrors are those whose polished surfaces are spherically hollow. The properties of those mirrors may

be easily understood, when we consider their surfaces as composed of an indefinite number of small planes, all of which make a determinate angle with each other, so as to throw all the rays to a point. Concave mirrors are used in the construction of reflecting telescopes.

The employment of concave mirrors in collecting the heat of the sun's rays from the whole of its surface to a single point, thus accumulating a very great degree of heat, for the combustion and fusion of various natural substances that are fusible in the greatest heat, capable of being produced from ordinary fire, may be exemplified, amongst those of modern date, by the burning-mirror of M. de Villette. The diameter of this metal speculum was 3 feet 11 inches, and its focal distance, or point from the surface was 3 feet 2 inches. The composition of this metal was of tin and copper, which reflects the light very powerfully and is capable of a high degree of polish. When exposed to the rays of the sun, a silver sixpence was melted in 7½ seconds when placed in its focus; a copper half penny melted in 16 seconds, and liquified in 34 seconds; tin was melted in 3 seconds; and a diamond weighing four grains lost seven-eighths of its weight.

Concave mirrors afford many curious and pleasing illustrations of their peculiar properties. For example; —when a person stands in front of a concave mirror, a little further from its surface than its focus (or half the radius of its concavity), he will observe his own image hanging in the air before him, and in an inverted position, this image will advance and recede as he advances or recedes; and, if he stretch out his hand, the image will do the same. Exhibitions have been brought before the public, in which a singular deception was practised by means of a large concave mirror. A man being placed with his head downwards, in its focus an *erect* image of him was exhibited, while his real person was concealed, and the place of the mirror darkened; the spectators were then directed to take a plate of fruit from his head, which in an instant was dexterously changed for a dagger or some other dangerous weapon.

Convex mirrors are chiefly employed as ornaments in apartments. The objects seen in these are diminished, but seen in an erect position; the images appear to

emanate from a point behind the mirror; this point, which is its focus, will be half the radius of convexity behind their surface, and is called the negative or imaginary focus, because the rays are not actually collected as by a concave mirror whose focus is called vertual.

The reflecting surfaces of cylinders have been occasionally used in optical amusements, for rendering distorted or deformed pictures of their proper shape when reflected from its surface.

Spectacles—These instruments are said to have been invented as far back as the year 1290. When two lenses are mounted in a frame to fix before the eyes, they are denominated spectacles, and are employed to render objects before the wearer more distinct. (See preceding article, Optics.) In the selection of spectacle-glasses great care should be used in examining them, and the first point of importance is the quality of the material of which they are formed; this should be free from all veins or small bubbles, for if one of these occur in the portion through which we look, it will greatly impair the eyes. The next circumstance is the colour of the glasses: the best adapted for general purposes is a pale blue. The figure of their surfaces should be perfectly spherical, for if they are curved more in one direction than in another, they will injure the sight, unless they are cylindrically formed, as for some particular disease. The polish should be clean, and free from flare, which too often arises from the manner in which they are usually polished on heterogeneous surfaces producing what is technically called a curdled glass. But above all things we should strongly recommend that persons who require the aid of spectacles, to refrain from purchasing from the itinerant venders who expose articles *made to sell*: sight is too valuable a blessing to be deprived off for the sake of saving a few pence, which will be all the difference in price between a *good* pair and a *bad* pair.

A *Telescope* is an optical instrument employed for viewing distant objects, by increasing the apparent angle under which they are seen without its assistance; and hence the effect on the mind of an increase in size, or, as it is commonly termed, *magnified* representation. The

construction of the Telescope is, perhaps, one of the most important acquisitions that the sciences ever attained, as it unfolds to our view the wonders of the heavens, and enables us to obtain *data* for astronomical and nautical purposes.

The inventor of this instrument is somewhat uncertain, and is ascribed to different individuals, as John Baptista Porta, Jansen of Middleburg, and Galileo. The time of its first construction was in the year 1590.

The *Microscope.*—The history of the microscope, like that of many other valuable inventions, has been veiled in considerable obscurity by the lapse of time; and the discovery amongst the moderns, of so useful a class of optical instruments has been claimed by several individuals. But it seems certain that the ancients were acquainted with the microscope, at least in one of its forms, as appears from the following passage in Seneca:—"Letters, though minute and obscure, appear larger and clearer through a glass bubble filled with water." Although we have no account that they understood the laws by which the magnifying power of the spherule was effected, yet their acquaintance with its application appears certain.

The invention of the microscope is attributed by the celebrated Dutch mathematician, Huygens, to a countryman of his, named *Drebell*, (for it must be observed it was entirely lost in the middle ages). He constructed them about the year 1621, or thirty-one years after the invention of the telescope. According to Borelli, the microscope was invented by Jansen, the reputed inventor of the telescope, who presented some instruments of his first construction to Prince Maurice, and Albert Archduke of Austria. These instruments were six feet in length, and consisted of a tube of gilt copper, one inch in diameter, supported by thin brass pillars in the shape of dolphins, on a base of ebony which was adapted to hold the object to be examined. Of the internal construction of this microscope we have no precise account; though there is reason to think that it was nothing more than a telescope converted into a compound microscope. Viviani, an Italian mathematician, says expressly in his Life of Galileo, that this great man was led to the construction of the microscope from that of the telescope; and in the year 1612 he actu-

ally sent a microscope to Sigismund, King of Poland. The honour of making a microscope of two double lenses like those at present in use (without their field-glass,) seems to belong to F. Fontana, a Neapolitan, who, in a work published in 1646, claims it as his own, and dates the invention from the year 1618.

The numerous forms of microscopes which have at different intervals been constructed, may be included in three distinct classes, however varying as to their external appearances;—these are *Single*, *Compound*, *Refracting*, and *Reflecting* Microscopes.

The *Magic Lantern* is constructed similarly to the solar microscope (vide Optics,) but having the object and field-glasses of larger diameters and longer foci, to admit more extensive objects; these objects are usually painted representations of familiar or grotesque objects on glass sliders, having the parts not occupied by the design blackened to obstruct the passage of light. These sliders are introduced by an opening cut in each side of the tube; the diameter of the lenses are nearly equal to that of the condenser or bull's eye, and are made to slide within the outer tube to adjust the image on the wall at different distances. A lamp is used to illuminate the lens.

Camera Obscura, or *Darkened Chamber*, is an optical apparatus for the representation of all surrounding objects, under the same angle which they subtend to the unassisted eye, and which are exhibited in their proper colour or shape, so as to enable a person to delineate or trace, both near and remote objects; without an acquaintance with the rules of perspective, when they are thrown on the paper.

In the construction of this instrument, a convex lens and plane mirror are its principal parts; these are arranged differently, according as it is required to be portable or stationary.

Although the modifications of this apparatus are numerous, they all depend on the same principle, which admits of the following improvement: the lens being convex, converges the rays that pass through it to the same distance from every part of its surface, but as the image is received on a flat plane, the rays will have to diverge farther than those in the centre, which are nearer

the lens; hence, the image will be a distorted representation of the object: to remedy this, when not required for tracing, the image should be formed on a concave surface. When, however, the instrument is wanted for the delineation of objects, Dr. Wollaston has proposed to make it *Periscopic* (from two Greek words signifying *seeing about*) by having the lens formed with such curves that the marginal rays are rendered longer than the central ones.

The *Kaleidoscope* is an instrument invented by Dr. Brewster while investigating the polarization of light, by successive reflections between plates of glass, in the year 1814 The patent he obtained for it, described it as a new Optical Instrument, "for creating and exhibiting beautiful forms:" this is effected by two reflecting plates inclined to each other, at any angle that is an aliquot part of a circle. These plates are placed between the eye and certain objects to form the intended picture; they are usually enclosed in a tube, and the objects, consisting of pieces of coloured glass, beads, &c., are loosely confined between two circular pieces of common glass, the one of which is usually *greyed* to make the light uniform. In order to give the picture varied outlines, threads of glass spun, or twisted, may be mixed with the pieces, being first formed into circles, ellipses, looped curves like the figure 8, curves like 3, or spirals like the letter S. On looking down the tube, through a small hole placed near the meeting of the plates, a beautiful circular figure will be seen, having six, twelve, or twenty angles, according to the inclination of the plates: these beautiful forms, by slightly turning the tube, will be changed, by which an almost infinite variety of patterns may be produced. From this instrument is derived many of the most beautiful patterns of the fancy shawls now manufactured.

In order to produce perfectly beautiful and symmetrical forms, Dr. Brewster found that the three following conditions are necessary:

1. That the reflectors should be at an angle which is an *even* or *odd* aliquot part of a circle, when the object was regular, and similarly situated with respect to both the mirrors, or an *even* aliquot part of a circle, when the object was irregular.

2. That out of an infinite variety of positions for the object both within and without the reflectors, there was *only* one position where perfect symmetry could be obtained, namely, by placing the object in contact with the ends of the reflectors.

3. That out of an infinite number of positions for the situation of the eye, there was *only* one where the symmetry was perfect; namely, as near as possible to the angular point, so that the whole of the circular field could be distinctly seen; and that this point was the *only* one out of an infinite number, at which the *uniformity* of the reflected light was a maximum.

GEOLOGY.

It is impossible to discover a study more interesting to an enquiring mind, than that which leads to an acquaintance with the numerous changes the globe we inhabit has undergone in past ages. If we can by any possiblity ascertain the order of those changes and the probable periods in which they were effected, it is clear that we may form a complete history of the earth, for the entire period necessary to produce the appearances within the reach of examination, as well as to infer, with something like certainty, the course of future revolutions. With respect to the origin of the materials composing the globe, science and observation can give us no information. But the changes to which they have been subjected, and the agents which have been most energetic in operating these changes, we can easily explore, with the certainty of acquiring information more and more correct as we proceed in our examination.

The science which employs itself in this interesting task is called Geology, or the study of the structure of the earth. A system which would account for the original birth and organization of the globe, is called *Cosmogony;* but no system of this nature can be more than a series of suppositions, strung together in some plausible order, or an hypothesis, since nature, since she offers us abundance of signs by which we many learn the changes to which she has been subjected, gives us no information of the period when she began to exist, or of the manner in which the material universe was brought into being.

The first idea which must suggest itself to any one who looks, even in the most superficial manner, on the natural objects by which he is surrounded, is, that every portion of the earth has undergone total, and, until they are accounted for, stupendous changes. If he dig a hole in a bog, he finds huge trees rooted in spots where now

there is only a shrubless morass; if he cut through the soil of a verdant meadow, he may find a bed of peat enclosing the trunks of trees; if he go still lower, he discovers a bed of clay, including the shells of fresh water fish; still lower the shells of sea fish will be intermingled; while below this last layer or stratum, the shells of salt-water shell-fish, or, as a naturalist would call them, marine testacea, which have no river or fluviatile species mixed with them. Again, a mountain stream, the sudden melting of ice, or an unusual frost, detaches a fragment from the side of a hill; and behold, similar layers of buried trees and shells, and bones, are suddenly exposed to view on the elevated mountain precipice! The native of the district collects some of these shells; he has never seen any like them before; no such fish inhabit the neighbouring lakes, or rivers, or ocean, and he preserves them in silent or ignorant amazement. At length a traveller arrives: to him the unknown curiosities are shown; and he redoubles the perplexity of the already astonished possessor by informing him that he has frequently collected similar shells inhabited by living fish on the shores of the Indian Ocean or the banks of some far away river. Ten thousand conflicting ideas now crowd upon the collector's mind. Curiosity so startlingly aroused cannot slumber until some satisfaction has been given to its restless spirit. Did these very objects before me once inhabit those distant climes where their species now reside? Were they swept from their original locality by the resistless force of some mighty deluge, and left to perish in these ungenial climes? He looks at the hill side, and the regular order in which he sees layer after layer deposited, checks this conjecture. Surely, had such been the cause of their transportation, masses would have been heaped upon each other in wild confusion. Can they then have once made this their home and dwelling-place? Was this once an expanse of waters fitted for the reception and support of creatures which require the heat of a tropical sun? If so, how can the climate have undergone so remarkable a change? Has the sun changed his course Such are his probable reflections, until he puts an end to his perplexities in one of those ways, according to the character of his mind. If his intellect be

restless, impatient and feeble, after revolving the matter once or twice, and "finding no end in wandering mazes lost," he discards it altogether from his thoughts as impracticable and useless; if he be a pert, conceited reasoning thing, ever skipping from conclusion to conclusion, with a sneer for all who do not imitate his agility, he straightway forms a supposition, quits his single trace of facts, and flits away to some new-topic. Should another traveller pay him a visit and detail new facts inconsistent with his hypothesis, he gives himself no trouble about that. Ignorance and self-conceit have a ready balm for such wounds, and he contents himself with thinking, if he does not absolutely remark, with the Frenchman, that it is "so much the worse for the facts." But if he has a patient reflecting spirit, a true desire for knowledge, and a proper sense of the united extent of his information—if in short, he is by nature and by habit a philosopher in the true sense of the word, he treasures up his acquired knowledge, and sets diligently to work to add to his store. He digs new holes, cuts the face of other hills, carefully observes the appearances offered to his view, and procures all the information in his power from those whose observations have been more extensive than his own, or carried on in another direction. Thus he may hope in time to acquire sufficient information to enable him to form some just idea of the causes of the various and apparently inconsistent appearances he has noticed. The first of these classes are evidently incapable of inquiring with effect into any subject. Numbers of the second, and a few of the third and rarest class, have occupied themselves in geology. Among those incomparably the most distinguished, is Professor Lyell, the Sir Isaac Newton of the science, whose views we shall now proceed to explain in as simple and as clear a manner as possible. Indeed it would be difficult to state Professor Lyell's views of the great laws which govern the changes to which the structure of the globe is liable, otherwise than simply and clearly; for simplicity is the characteristic of all the great laws of nature; and when once elucidated, they appear to have been from the first a most obvious solution of the phenomena or appearances.

Like all other great philosphers, or men who have been

remarkably successful in developing the laws of nature, Professor Lyell has constructed his simple hypothesis upon an almost boundless accumulation of facts. In the industry with which he has amassed information respecting the state of the globe, and the cautious use he has made of his materials, he has no superior except the great master of human knowledge, Aristotle, and the reviser of the true Aristotelian mode of philosophising, Lord Bacon.

Before proceeding to explain Lyell's system, it is necessary to point out some of the errors he has to combat. Hitherto, geologists, when at a loss to account for the traces everywhere left on the face of the earth of gigantic change, have called into their aid the unbridled violence of the elements. They have supposed the earth at some past eras to have been seized with convulsive paroxysms, which have dislocated all its parts, and shattered its very frame-work. That after these chaotic agitations, it has again settled down into a comparatively quiescent state. In one of these happy intervals we at present exist, warned only of the lurking energies which have wrought these tremendous results, and which may again probably annihilate, in one vast explosion, the present order of things, by the low growl of some insignificant volcano, the slight tremor of a local earthquake, or the ravages of a partial inundation. These philosophers wielded the powers of nature much in the same way as the prae-Newtonian astronomers did the frame-work of the heavens. As the latter lavished upon the celestial architecture spheres, cycles and epicycles, without end, "to save the phenomena," so have the former discharged the earthquake, the volcano, the deluge, with remorseless fury over the fair face of creation. Were they at a loss to account for the elevation of a mountain ridge? Straightway the subterranean mines were charged, and an explosion, which would shake creation to the centre, shot the Andes up into the air. Were they perplexed by the remains of marine animals on the tops of lofty mountains? Some sudden inversion of the planet hurled an ocean over the heights, and transported thither fragments and relics from the most opposite and distant regions. Such was the recent state of the science of geology. The entire theory of paroxysms and convulsions was as

completely a tissue of inventions, supported by no analogy in nature to account for appearances, as the sycles and epicycles of the astronomers. However, Newton arose, and by the announcement of the simple law of gravity, put an end for ever to the din of conflicting spheres, and the dizzy maze of centric and eccentric orbs. The simple fact announced by Professor Lyell, as the result of extensive observation and calculation, which is to dispense with these periodical returns of agitation, is, that the operations of nature, as seen around us from day to day, are fully adequate to the production of every change which we can ascertain to have taken place in the structure of the globe. He tells us that we may daily see processes going on, which, though insignificant to our limited and brief opportunities of observation, are yet sufficient, by their ceaseless operation, to level the loftiest mountains, fill the profoundest depths, dissipate existing continents, and elevate into their place the "ooze and sunken bottom" of the present ocean.

To do justice to his theory, we must consider it under two divisions—the agencies by which these changes are to be effected, and the most probable popular objections to which it may be liable. These agencies are divided into two principal classes—organic and inorganic; that is to say, agents endowed with life, and those not endowed with life, or animals and vegetables. The inorganic changes are again subdivided into aqueous and igneous. The aqueous are streams, springs, tides, and currents. The igneous are the earthquake and volcano. These causes, incessant in their operation, are sufficient, according to Lyell, to produce every change which can be traced in the structure of the earth, and in the distribution of sea and land. To establish this theory, he has collected an astonishing multitude of facts, comprehending almost all the remarkable earthquakes, eruptions, landslips, and floods recorded in the annals of time. He shows us how the rivers are incessantly wearing down the hills from which they spring, and the soil through which they flow, and conveying the materials to the ocean; how tides are continually filling up arms of the sea, and conflicting currents excavating the floor of the ocean in one place, and heaping up huge accumulations in others. He tells us how earthquakes have occasioned

the sudden subsidence or sinking] of land in some quarters, and volcanoes have raised new mountains and islands in others. These changes have actually been effected during the very brief period of which we have any records. Now, then, if the same causes continue to operate through an indefinite series of ages, they are obviously sufficient to produce a total revolution in the aspect of the globe, and, in the lapse of time, to restore it again to its present condition. Thus we can ascertain that within the last two thousand years, the upper part of the Adriatic has received accessions of land of many miles in extent from the deposits left in it by the Po, the Adige, and other rivers descending from the Alps. How can we, therefore, avoid the conclusion, that in process of time, that gulf must become an alluvial valley, bounded by the Appenines on the west, and its present mountainous shores on the east, and irrigated by the lengthened Po wandering through the centre? Having once pictured such a result in our imagination, as the certain consequences of causes now in operation, we have only to turn our eyes to the great valleys through which many existing rivers flow, to recognize at once the process of their formation.

A recent intelligent traveller in the Highlands and Islands of Scotland, describes his astonishment and delight in discovering the seas on the west coast filled with living creatures, all of which were engaged in the process of forming land. He perceived that the sea from Shetland to the Mull of Cantyre was filled with animals like glittering sand, each of which, on inspection, was found to consist of a minute spiral, resembling the worm of a ramrod, but not the hundredth of an inch in diameter. So numerous were these, that the water seemed muddy with their presence; and he calculates, that if all the hairs on the heads of the men, women and children, born since the beginning of the world, were enumerated, and all their separate hairs were lives, these would not amount to one generation of this spiral people, born on Monday morning to die on Wednesday night, and so on for ever and ever. Such an infinite number is absolutely appalling* But even this is nothing, when it is found

* The late Dr. Chalmers in speaking of the boundlessness of the creation says "About the time of the invention of the telescope, another

that the intervals between these are filled by fifty different kinds of creatures, each of them fifty times smaller, and all engaged in the same endless occupation. The invisible insensible toils of these ephemeral points, conspiring with others in one great design, working unseen, unheard, for ever, guided by one volition, by that One Volition which cannot err, converts the liquid water into the solid rock; their bodies die, sink and concrete; the bottom of the ocean, and the shores of islands, are gradually elevated by the morbid deposit; the deep ocean is at length converted by them into dry land, and extends the dominion of man, who sees it not, and knows it not, over regions which even his ships had scarcely traversed. Thus the great Pacific, by other means than that of the alluvium of of inflowing rivers, is destined at some future day, to be a new continent.

Facts like these are enough, in our estimation, to indicate the principle of Professor Lyell's theory—a principle which was in fact recognized by some of the ancient philosophers. Indeed it is not to natural objects alone that the great principle of revolution of decay, and repro-

instrument was formed, which laid open a scene no less wonderful, and rewarded the inquisitive spirit of man. This was the microscope. The one led me to see a system in every star; the other leads me to see a world in every atom. The one taught me that this mighty globe with the whole burden of its people and its countries, is but a grain of sand on the high field of immensity; the other teaches me that every grain of sand may harbour within it the tribes and the families of a busy population. The one told me of the insignificance of the world I tread upon; the other redeems it from all its insignificance; for it tells me, that in the leaves of every forest, and in the flowers of every garden, and in the waters of every rivulet, there are worlds teeming with life, and numberless are the glories of the firmament. The one has suggested to me, that beyond and above all that is visible to man, there may be fields of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the universe. the other suggested to me, that within and beneath all that minuteness which the aided eye of man has been able to explore, there may be a region of invisibles; and that, could we draw aside the mysterious curtain which shrouds it from our senses, we might see a theatre of as many wonders as astronomy has unfolded, a universe within the compass of a point so small as to elude all the powers of the microscope, but where the wonder working God finds room for the exercise of all his attributes, where he can raise another mechanism of worlds, and fill and animate them all with the evidence of his glory."

duction, is applicable. Every succeeding addition to our knowledge appears to bring us back more and more directly to the views of the leading ancient philosophers, as though science, as well as the material world, had its periods of use, decay, and restoration. Every successive discovery of modern times appears to point more plainly to the principles of the ancients, as though all that we know had been known before, all that we discover had been discovered before, and the results only to have survived. The process by which the early philosophers arrived at those results has perished; hence doubt and contempt have been thrown upon them by conceited ignorance, until philosophy, after re-exploring the arcana of nature appears to be finding her way once more in her original resting places. So true it is that there is nothing new under the sun.

In a limited sketch like this it is impossible to do more than indicate the line of argument followed by Professor Lyell's Principles of Geology. For the ample details of facts calculated to establish its truth, we must refer to the work itself which will be found well worth an attentive perusal.

Let us, however, consider one or two of the objections most likely to occur to plain people when the theory is first explained to them. Many persons are very ready to follow reasoning to a certain extent, who, when a more startling result is presented to them, find it impossible to assent, although it may be quite as fair a deduction as the former. For example, a man may say "I can easily believe you, when you tell me that a peat-moss was once a forest, and that it was so less than two thousand years ago, when in addition to the undeniable remains of trees, many of them still rooted in the ground which I observe, I find beneath it the traces of a Roman road, and hear that the historians of that people mention the spot as a wood; but when I see a bed of coal, of prodigious thickness, extending quite across the bed of the Forth, at a considerable depth, and you call on me to believe that that too was once vegetable matter, I am confounded, I cannot go along with you." The only way to meet such persons is to shew them some equal or greater wonder going on before their eyes in a manner which they cannot deny. Detail to him, then, what is now going on at the

mouth of the Mississippi, and his incredulity must give way. In addition to the incalculable quantity of loose drift timber annually carried down, and imbedded in the Gulf of Mexico by that enormous stream, there was a single raft formed of torn-up trees, ten miles long, two hundred and twenty yards wide, and eight feet deep; the whole of which was accumulated, in consequence of some accidental obstruction, in the course of a few years. How insignificant then, must this mass of timber, enormous as it is, be, when compared to what must have accumulated, in the course of centuries at the mouth of the river. When the progress, making daily, in shallowing the gulph is ascertained, it requires no distant geological view to look forward to a time, when that expanse of water will be converted into a vast alluvial plain, through the centre of which, the mighty stream will roll its extended course towards "the bated and retiring waters" of the Atlantic. Our objector will now at at once perceive, that, whenever such a time shall come, there must be found beneath the bed of the river strata of vegetable origin, more extensive than imagination can conceive.

There may be no analogy between the actual cases, but the one is not more wonderful than the other; and, on the other hand, they might have been similar. A single fact may sometimes occur, so intelligible and undeniable, as to have greater weight, with many minds, than the most ample evidence collected from quarters less accessible and obvious. Thus, the tree found a few years since in Craigleith quarry, in the vicinity of the city of Edinburgh, was enough to convert the most obstinate disbeliever into a confirmed geologist. There it was—no child could see it and doubt that it was a tree—the bark, the bend in the trunk, the spot whence branches had been rent, were all too plain to admit of a moment's doubt. Moreover it lay imbedded fifty or sixty feet deep in solid rock. "How did it get there?" was the question. Plainly, the rock could not have been rock when the tree got into its bosom. What alterations of flood, earthquake and volcano might have been brought into play for the purpose of inserting the hapless monarch of the antidiluvian forest in the spot where it unquestionably was found, it is impossible to say. Fortunately, Captain Basil Hall had

shortly before published a volume of travels in which occurred the following passages.

"Some years ago, when the Mississippi was regularly surveyed, all its islands were numbered, from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number, but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are entirely melted away—at other places they have attached themselves to the main shore, or, which is the more correct statement, the interval has been filled up by myriads of logs cemented together by mud and rubbish. When the Mississippi, and many of its great tributaries overflow their banks, the waters, being no longer borne down by the main current, and becoming impeded amongst the trees and bushes, deposit the sediment of mud and sand with which they are abundantly charged. Islands arrest the progress of floating trees, and they become in this manner re-united to the land; the rafts of trees, together with mud, constituting at length a solid mass. The coarser portion subsides first; and the most copious deposition is found near the banks where the soil is most sandy. Finer particles are found at the farthest distances from the river, where an impalpable mixture is deposited, forming a stiff unctuous black soil. Hence the alluvions of these rivers are highest directly on the banks, and slope back like a natural glacis towards the rocky cliffs bounding the great valley. The Mississippi, therefore, by the continual shifting of its course, sweeps away, during a great portion of the year, considerable tracks of alluvium which were gradually accumulated by the overflow of former years, and the matter now left during the spring floods will be at some future time removed. One of the most interesting features in this basin is 'the raft.' The dimensions of this mass of timber were given by Darby, as ten miles in length, about two hundred and twenty yards wide, and eight feet deep, the whole of which had accumulated, in consequence of some obstruction, during about thirty-eight years, in an arm of the Mississippi, called the Atchafalaya, which is supposed to have been at some past time a channel of the Red River, before it intermingled its waters with the

main stream. This arm is in a direct line with the direction of the Mississippi, and it catches a large portion of the drift wood annually brought down. The mass of timber in the raft is annually increasing, and the whole rises and falls with the water. Although floating it is covered with green bushes, like a track of solid land, and its surface is enlivened in the autumn by a variety of beautiful flowers. Notwithstanding the astonishing number of cubic feet of timber collected here in so short a time, greater deposits have been in progress at the extremity of the Delta in the Bay of Mexico."

This settled the matter at once; nothing could be more plain; the rock was sand when the tree was swept down and imbedded: its very position is described as exact as though the Captain had had his eye upon it when writing. This rock, then, was once sand; and a river capable of sweeping down trees of such dimensions as this, held its way over the spot where the quarry is now situated. This is certainly evidence of gigantic change, of revolution, which it makes a person giddy to contemplate; yet after all, the very same process is at this very moment going on, on the other side of the Atlantic. We may there see, actually in progress, operations, to the results of which this apparent wonder is the fac-simile. With many minds incapable of doing justice to cumulative evidence, one fact so obvious as this would be decisive.

There is another class of objectors, whose doubts we are particularly anxious to remove, because, although their objections arise purely from ignorance, yet their motive and feelings are entitled to respect. Persons of imperfect education, unaccustomed to the contemplation of philosophical subjects, too often derive their only notion of the formation of our earth from the account given in the first chapter of Genesis. As that account is very brief and general, it is totally impossible that such persons should acquire any but the most confused and imperfect ideas. Studied, indeed, by the light of philosophy, illuminated by knowledge drawn from that ample revelation of his works, which the Divine Being has vouchsafed to all his creatures in the great volume of nature, its unexplained announcements are felt to be

invested with the inaleniable sublimity which belongs to the simple enunciations of mighty truths. The revealed Word of God as contained in the Holy Scriptures is one only of the manifestations which he has been pleased to make of himself. Its extent has hitherto been limited; its object is clearly defined, to inform man respecting his relation to his Maker, to unfold to him his immortal destiny, and to instruct him how he may become fit for future happiness. It is in no way intended to supply us with information upon natural philosophy. The great volume of nature is spread before us, on which we may see the history of the works of God traced in characters admitting neither of obliteration nor mistake. The incidental notices, therefore, of such topics, occurring in the written word of God, must be understood and explained by a reference to the more explicit revelation granted for that purpose. The immeasurable spaces of time required by the geologist, especially under the system we are considering, to produce results which can be undeniably shown to have taken place, will appear to any who understand the usual account, in a certain sense inconsistent with its details. Though this error may in the present day be confined to very ill-educated or childish persons, yet there was a time when it was dangerous for a philosopher to give an opinion on any natural phenomena inconsistent with the ordinary expression of sentiment. Galileo was consigned to a dungeon for asserting that the earth revolved round the sun, whereas it was argued that the sun came forth from the east, and ran his course to the west. Buffon was compelled by the doctors of the Sarboune, to recant his theory of the formation of the earth, because it was thought contradictory to the narrative of Moses; and in our own country, many philosophers little more than a century ago, were exposed to obloquy if not persecution, from the same propensity to adduce the authority of Scripture on topics foreign to its purposes.

Let none then fear that his religious belief can be endangered by the rational and unfettered study of nature. It is our duty to study God, in his works and in his word, and to seek in each that peculiar instruction which they are generally intended to afford. Their lessons, if read aright, will infallibly be found to reflect mutual

lustre; distinct, but not discordant; differing indeed, in dignity, but each bearing the visible impress of the same origin.

THE THERMOMETER.

ITS HISTORY AND CONSTRUCTION.

The invention of the thermometer, like almost every discovery of great utility, has been claimed for different philosophers; and national vanity has occasionally been enlisted in support of the rival claimants. There seems but two, however, whose titles are worthy of notice.

The Italian writers generally give the honour to their countryman Santorio Santorio, long a physician at Venice, and afterwards a professor at Padua, who flourished about the beginning of the seventeenth century, and who had obtained just celebrity by his discovery of the insensible perspiration of the animal frame. The Dutch philosophers, on the other hand, unhesitatingly ascribe it to Cornelius Drebbel, a physician of Alkmaar, who appears to have enjoyed a high reputation as a chemist, a mathematician, and an inventive mechanical genius.

Santorio expressly claims the invention as his own, and he is supported by Borelli and Malpighi. The title of Drebbel is considered as undoubted by Boerhave and Musschenbroek. It would now, perhaps, be difficult to decide the controversy; but it is worthy of remark, that Santorio who was born in 1561, and died in 1636, did not publish his claim to the invention till 1626; and although thermometers are alluded to by Robert Flud, within the first quarter of that century, yet as he travelled both in Germany and Italy for six years, we can draw no inference from that circumstance. Certain it is, that thermometers were constructed about the same time, both in Italy, and in Holland, on the same principle; and though the instruments of Drebbel were well known in

Holland and England before the fame of Santorio appears to have reached the North West of Europe, the most recent writers have generally considered the latter as the real inventor of the thermometer. It is, however, by no means improbable, that each may be justly entitled to the merit of a discoverer.

Be this as it may, the instrument, from its imperfect construction, was of very little use in the hands of either, and required the successive labours of different philosophers to render it a tolerably accurate indicator of the variations of temperature.

The thermometer, ascribed to Santorio and Drebbel, is precisely the same in form and principle. It consists of a glass tube, with a ball blown on one if its extremities, and having the other end open. A portion of the air in the ball is expelled by heat, and then the open end of the tube is immersed in any liquid contained in the cup. As the ball cools, the included air diminishes in volume, and the liquid is forced into the stem by the pressure of the atmosphere, until it replaces the volume of air which was expelled by the heat. When a heated body is applied to the ball, the air will again be expanded, and depress the liquid in the stem; and if this stem be a cylinder, a scale of equal parts applied to it will enable the observer to form some idea of the difference between the relative temperature of bodies applied to the ball. On the removal of the heated body, the volume of the included air again diminishes, and the liquid again rises in the stem by atmospheric pressure, until the elasticity of the air within the instrument is in *equilibrio* with that of the surrounding atmosphere. Instruments constructed on this principle are called *Air Thermometers;* because their action depends on the elasticity of air; and from their having been originally employed to mark the changes of atmospheric temperature, they are described by the older writers under the name of weather-glasses; a denomination also given to barometers.

Drebbel appears to have devised a variety of the instrument more delicate in its indications. The globular form of the common bulb, and its small size, rendered it less susceptible of slight changes than a flattened bulb of larger diameter.

In the obscure and often almost unintelligible writings of

our countryman Dr. Robert Flud, published at the beginning of the seventeenth century, frequent mention is made of the thermometer, or as he calls it *speculum calendarium;* and the common air is repeatedly figured in his singular work, *De Philosophia Moysiaca*, published in 1638, with its stem divided equally into an ascending and descending series, each of seven degrees, respectively appropriated to summer and winter. It is obvious that the size of an air thermometer, on such principles, is only limited by convenience, and the length of the column of liquid which the pressure of the atmosphere can sustain in the tube. As originally made, they were unwieldy, they could not be applied to high temperatures, and were besides, liable to two very important objections, as indicators of the atmospheric changes of temperature,—they were liable to be affected not only by heat and cold, but by the varying pressure of the atmosphere and the scales adapted to them were arbitrary, and without fixed points for the comparison of observations made with different instruments.

The first objection was foreseen and obviated by the scientific members of the Florentine Academy, assembled under the patronage of the Grand Duke of Tuscany. In the first article, in the published transactions of that learned body, we find a full description and delineation of a thermometer from which the influence of atmospheric pressure is excluded. The expansion of spirit of wine is employed to ascertain the temperature, instead of the dilatation of air; and the instrument is sealed *hermetically*, as it is termed, or has its orifice closed by melting the glass, after the introduction of as much spirit as fills the bulb and a portion of the stem. The method employed by the Florentine academicians is nearly that still used by the makers of the instrument; namely, by heating the bulb in the flame of a lamp, to expel the air, and then immersing the open end of the tube in the liquid destined to fill the thermometer. As the ball cools the atmospheric pressure forces the liquid into the stem and ball, to supply the *vacuum;* and the orifice is closed by melting with the blow-pipe the end of the tube, from which any excess of the liquid may be previously expelled by again heating the ball.

The Florentine Academicians appear also to have been

aware of the necessity of adapting some fixed scale to the tube; but their attempts were not very successful. They described the thermometer as consisting of a ball and tube of such relative size, "that on filling it to a certain mark of its neck with spirit, the cold of snow and ice will not cause it to fall below 20 degrees measured on the stem; nor, on the other hand, the greatest heat of summer expand it more than 80 degrees." This method is evidently erroneous, inasmuch as the last point could be of no determinate temperature: and their system of graduation is in itself rather rude. The tube is directed to be divided by compasses into ten equal parts, these divisions are to be marked "by a little button of *white* enamel; and these may be further subdivided by the eye, and the intermediate degrees marked by buttons of glass, or of *black* enamel."

This instrument was variously modified by them to suit different purposes. The ball was occasionally enlarged, and the tube reduced in thickness to render the instrument more sensible; and in the work already quoted, we find a figure of a thermometer of this sort with the stem spirally twisted to render it more portable, and less liable to accident.

Another invention of the Florentine academicians to indicate changes of temperature may be here noticed. It consisted of hermetically sealed spherules of glass, of different specific gravities, introduced into a wide tube filled with pure spirit. The degree of the Florentine thermometer at which each sank was noted, and by hanging this instrument in an apartment, it somewhat showed the variations of the temperature of the surrounding air, though slowly. Imperfect as these attempts were, they paved the way to very important improvements in thermometers.

The indefatigable Boyle appears early to have turned his attention to the improvement of the thermometer, and his first attempts were on the air thermometer, or the weather-glass, as it was then styled. He rendered the instrument more convenient, by making one reservoir for the liquid and for the air at the bottom of the tube; and thus the thermometer might be conveniently dipt in a fluid, or applied to any body for ascertaining its temperature. "The thermometer," he says, "being made by the

insertion of a cylindrical pipe of glass (open at both ends) into a phial or bottle, and by exactly stopping with sealing wax, or very close cement the mouth of the phial, that the included air may have no communication with the external, but by the newly mentioned pipe." If a portion of any liquid sufficient to cover the lower extremity of the pipe be contained in the bottle, it is obvious, that the expansion of the enclosed air will elevate the included liquid in the cylindrical pipe; and this liquid will again descend on the contraction of the enclosed. Mr. Boyle likewise showed that no dependence could be placed on the indications of open air thermometers under different degrees of atmospheric pressure; and he states, that on plunging the bulbs of different thermometers in liquids of very different specific gravities, as mercury and water, the liquor in the stem stood at unequal heights though both had been long exposed to the same temperature.

The Florentine thermometer was about that time introduced into England, and duly appreciated by both Boyle and Hooke. The specimen seen by these philosophers was filled with *colourless spirit*, but they made use of spirits of wine, tinged by cochineal, "of lovely red;" and, says Boyle "'tis pleasant to see how many inches a mild degree of heat will make the tincture ascend in the cylindrical stem of one of these useful instruments." Boyle was fully aware of the imperfection of the scales hitherto applied to the thermometer, and sought to discover a remedy. He proposed to obtain a fixed point in the scale by marking the height of the liquid in the stem of the instrument, when the ball was placed in thawing oil of aniseeds, a point which he preferred to that of thawing ice, because the former could be obtained at any period of the year. His method of making two or more comparable thermometers, however, would be found extremely difficult, if not impossible in practice; it is best explained in his own words—"For if you put such rectified spirit of wine into a glass, the cavity of whose sperical, and that of its cylindrical part, are as near as may be, equal to corresponding cavities in the former glass, you may by some heedful trials, made with thawed and recongealed oil of aniseeds, bring the second weather-glass to be somewhat like the first; and if you know the quantity of your spirit of wine you may easily enough

make an estimate, by the place it reaches to in the neck of the instrument, whose capacity you also know, whether it expands or contracts itself to the 40th, the 30th, or the 20th part of the bulk it was of, when the weather-glass was made."

Boyle mentions that an "*ingenious man*," (alluding to Hooke) had proposed the freezing of distilled water as a fixed point in the scale of thermometers, but he himself evidently gives the preference to the congealing point of aniseed oil. Dr. Halley proposed to regulate the scale by the uniform temperature of such a cavern as that under the Observatory of Paris, or the point at which *spirit boils;* and he also suggested the fixing of the scale from the *boiling of water*. This point he considered as an invariably fixed one, not liable to alteration from external circumstances; and the same idea was entertained by Amontons. With a single point so fixed, the method attempted by Boyle,, Halley, and Hooke was to calculate the proportion of the stem to the ball, and thus to determine the increase in bulk of the whole liquid by a certain temperature.

Dr. Hooke appears invariably to have used in his thermometers spirits of wine "highly tinged with the lovely colour of cochineal, which he deepened by pouring in it some drops of common spirit of wine."

The sagacity of our illustrious Newton saw the importance of improving thermometers. He appears to have been early aware of the inconvenience of spirit as a thermometric fluid, and employed linseed oil to fill his thermometers. It has the advantage of being able to endure a very considerable temperature without endangering the bursting of the tube, and therefore can be applied to a higher range of temperature than a spirit thermometer. It has the disadvantage however, to be more sluggish in its movements, and to adhere much to the inside of the tube while it differs greatly in its fluidity at different temperatures. Newton perceived the convenience of having two fixed points in the contruction of the scale; and he used the freezing and boiling points of water as the most suitable for this purpose.

Newton continued his scale of temperature farther by observing the rate of cooling of heated bodies, until he could apply his thermometer to them, on the principle

that equal decrements of temperature take place in equal times. It was thus he estimated the temperature of iron heated to the utmost intensity of a small kitchen fire equal to 194 degrees, and in a fire of wood about 200 or 210 degrees of the same scale.

It is perhaps unfortunate for the philosophy of heat that more sublime and dazzling objects drew Newton's attention to other pursuits. Though he led the way to just views of the subject, neither he nor any of his predecessors appear to have been aware of the influence of the varying atmospheric pressure on the boiling points of liquids; nor do any of them to have considered that the varying expansions of the thermometric liquids at different temperatures, and the expansions of the glass of the instrument, must have materially affected every attempt to subdivide the stem of the thermometer into fractional parts of the whole bulk of the contained liquid.

One of these questions, however, seems to have about that time engaged the attention of philosophers, viz., whether equal increments of temperature caused equal expansions of the thermometric fluid. Dr. Brooke Taylor tried the experiment with an oil thermometer, by mixing definite portions of hot and cold water, and measuring the temperature of the mixture. His conclusion was in the affirmative, but the delicacy of his instruments was unequal to the solution of this nice problem, although he has the merit of pointing out how the problem is to be solved.

The Memoirs of the French Academy of Science contain several descriptions of thermometers, and an account of many interesting observations with these instruments; but the first alteration in their construction deserving of notice is the air thermometer of Geoffroy which, from the short description, appears to be an improvement on that of Boyle, inasmuch as it is not affected by atmospheric pressure. He describes his tube as without any opening, except one, which descends almost to the bottom of the ball, and there dips into a small portion of coloured liquid. It is not stated how the ball was joined to the tube, but it was most probably by cement.

M. Amontons clearly saw the importance of fixed points in the thermometric scale, and proposed to obtain them from the boiling point of water. His thermometer

consisted of a tube four feet in length, ending below in a ball bent upwards, and open at the upper extremity. The measure of the temperature was the elasticity of a given portion of air included in the ball, and subjected to a pressure equal to two atmospheres by adding to the usual atmospheric pressure that of a column of mercury of 28 French inches, which is equal to 56 inches under the usual pressure.

Although the idea of Amontons' was a fine approximation to a universal standard for a thermometric scale, the instrument is liable to such objections, that its principle seems scarcely ever to have been put in practice, except by its inventor.

While these attempts to perfect the thermometer were making in France, important improvements on it were effected in Germany and Holland, by the introduction of quicksilver as the thermometric fluid.

Science is indebted to Roemer, the celebrated astronomer of Dantzic, for this improvement, to whom the invention is ascribed by Boerhave, as well as the first idea of the scale now known as that of Fahrenheit. Thermometers of this construction were made by Gabriel Fahrenheit, a native of Dantzic, in so perfect a manner, that he has generally been considered as the original inventor; they were speedily spread over the north of Europe under his name, and to this day they maintain their acknowledged superiority in several countries, especially in Great Britain.

The mercurial thermometer was used by the Italian philosopher, Renaldini, before the end of the seventeenth century; and he proposed an ingenious method of graduating it between the freezing and boiling points of water, by successive mixtures of determinate weights of boiling and ice cold water.

The great advantage of Fahrenheit's thermometer over every other previous invention, consisted in its applicability to a greater range of temperature, from the freezing to the boiling points of quicksilver; in its not soiling the containing tube, and in its receiving the impressions of heat and cold more readily, while its density rendered capillary tubes filled with it perfectly visible; and thus the instrument became more portable and delicate. We may also remark, that at the period of its invention there

was no other scale in use that could pretend to vie with it in accuracy; and it still possesses such peculiar advantages that the observer is seldom troubled with negative degrees, and from the number of its divisions has rarely, in ordinary operations, to use fractions of a degree.

It would now be a waste of time to describe the various thermometers which were in use in France and England before the time of Fahrenheit. They were all without fixed points in the scale; and though they were vaunted as constructed after the models in the Royal Observatory at Paris, or in the apartments of the Royal Society of London, they gave most incongruous results. We shall therefore pass to the

Precautions necessary to be observed in constructing accurate Thermometers.

A general idea has been already given of the mode of constructing a thermometer, but where so much accuracy is required there are many niceties that demand attention.

1. The tube should be of equal diameter throughout the whole stem. As obtained from the glass-house, the tubes are in reality frusta of very elongated hollow cones, which, by extension, become more or less nearly cylindrical, and as the divisions of the scale are usually equal, it is very important that the tube should not perceptibly differ from a true cylinder.

For these purposes, after a tube has been chosen by the eye as equal in calibre as possible, the best makers blow a bulb on it, and introduce a short column of mercury into the stem, perhaps an inch in length, which is accurately measured on a fine scale of equal parts, in different portions of the tube, as the column is, by the heat of the hand, moved from the bulb to the open extremity of the tube. Should the mercurial column subtend the same number of divisions on the scale in every part of the tube it may be considered as a perfect tube for a thermometer.

The late Mr. Wilson of Glasgow, introduced thermometric tubes of an elliptical bore. The advantage of this form is, that a very small column of mercury is much more visible when it is expanded at right angles to the line of vision. If due precaution be taken to ensure the equality of the tube, this form answers well, especially

for ordinary purposes; but where great nicety is required, we would recommend the cylindrical tube.

2. The form and proportion of the bulb may vary according to the purpose for which it is to be applied. The larger the bulb in proportion to the stem so much more delicately susceptible of changes of temperature will be the thermometer. The spherical bulb is to be preferred, for this shape is least likely to be affected by the varying pressure of the air; but when the bulb is very large, this form renders the thermometer less susceptible of minute changes of temperature, and pyriform or cylindrical bulbs are usually adopted.

In forming the bulb the mouth must not be employed to blow it, otherwise moisture will condense in the tube, which is expelled with much difficulty and if suffered to remain, will greatly impair the value of the thermometer. Good instrument makers use a small bottle of caoutchouc, or elastic gum, fastened by a thread on the end of the tube, while the other extremity is softened by the flame of a tallow lamp, urged by a blow pipe. By compressing the bottle, after the orifice of the softened end of the tube is closed by the aid of another rod of glass, a bulb is formed of any required size; but a neat workman will rarely consider the first blown bulb sufficiently well formed for his purpose. It is generally dilated till it bursts; the glass, while still soft, is compressed into a rounded mass, and a fresh bulb formed of a regular shape and size proportioned to the calibre of the tube. Should the artist not intend to seal the tube immediately, he usually hermetically seals the other end of the tube to prevent the entrance of damp air and dust.

3. The necessary precautions used in filling thermometers with mercury are plainly pointed out in Nicholson's *Chemistry*, viz:—

The mercury should be clean, dry, and recently boiled, to expel air as much as possible. Mercury is often cleaned by thermometer makers by agitating it in a phial, for sometime, with sand, and then straining it through leather; for rice instruments it should be distilled from iron filings, or reduced from its sulphurets in clean iron vessels at a moderate heat.

The bulb, to be filled, is heated in the flame of a lamp, and the open extremity of the tube is immersed in the

mercury; as the bulb cools, the pressure of the atmosphere forces the fluid into the tube and ball. The bulb should be but moderately heated at first, so as on cooling to become only half filled.

4. To ensure a delicate thermometer the mercury is next to be boiled in the thermometer. For this purpose a slip of clean paper is to be rolled tightly round the upper part of the tube, so as to form, beyond the orifice, a cup or cylinder capable of containing as much mercury as the bulb: secure this round the tube with a thread, put a drop of mercury into the paper cavity, and again apply the heat to the bulb, holding the tube by the part covered with the paper, the mercury will soon boil, and about one half of the contents of the ball will rush up into the paper cup. On removing the bulb from the candle the mercury will suddenly return. Repeat this operation again and again, until the speedy boiling of the mercury, and the diminished noise and agitation show that the whole has been well heated, and air and moisture expelled from it. Should there be the least moisture in the tube before this part of the operation, it is very likely to burst the bulb; and the same accident is likely to happen, if the mercury be too strongly boiled the first or second time.

5. The tube is now to be *hermetically sealed*, that is, closed by the fusion of the glass at the upper extremity, which for this purpose is previously drawn to a capillary orifice. When it is intended to free the tube entirely from air, which is the best method with mercurial thermometers, heat is again to be gently applied to the bulb, which at the same moment is to be softened by another flame, and closed in the usual way, as soon as the mercury reaches the extremity of the tube. When the ball has cooled a little the sealing is rendered more secure by fusing the glass more fully around the top, so as completely to obliterate the orifice. If the vacuum be perfect, the mercury will fall to the extremity of the tube, on inverting the thermometer, unless the calibre be absolutely capillary; in which case capillary attraction will overcome the force of gravity, and the mercury will retain its position in the tube, in every situation of the instrument. Where there is a complete vacuum in the tube, the mercury must be well boiled before the sealing, as above directed;

and when we choose a thermometer, the ready falling of the mercury, on inversion of the tube, is the best test we can have that the mercury has been well freed from air and moisture. This vacuum is not, however, so essential to the true action of the thermometer as was once supposed. A thermometer with a small dilatation of the tube when sealed, containing some common air, has lately been recommended as preferable to the instrument with a vacuum on the surface of the mercury.

6. We come now to the last and most delicate step of the process, the adaptation of the scale to the instrument.

In the manufacture of thermometers this is conveniently done by plunging the new instrument, along with a standard thermometer into two liquids at different temperatures: but the graduation of this standard instrument is a work of such nicety and importance, that a committee of seven members of the Royal Society was formed to investigate the subject, and their elaborate report is given in the Society's Transactions, where all the requisite circumstances are distinctly noticed, and the best manipulations minutely described.

Two fixed points are sought, and the freezing and boiling points of water are most convenient for that purpose. To find the first, nothing more is necessary than to place the thermometer to be graduated, after it is filled, in melting snow, or ice, in such quantity around the ball and tube, as to bring it to the desired temperature. When the mercury has become stationary in the tube, a mark is to be made on the tube with a file, just opposite to the top of the mercurial column; and that mark fixes the freezing point of the scale of the instrument. The determination of the boiling point is much more difficult, because it is affected by atmospherical pressure, and even by the form of the vessel in which the water is heated. The Committee of the Royal Society recommend that the boiling point ought to be fixed under a barometrical pressure of 29. 80 inches.

CHEMISTRY.

CHEMISTRY acquaints us with the various means of changing the properties of their bodies, by their action upon each other, whether in a simple or a compound state.

Chemistry is a science the utility of which is as boundless as its extent. What grasp at the knowledge of terrestial things can be conceived wider than that which embraces the action of all bodies, under all circumstances, upon each other; or what can be more important to the enjoyment of physical existence, than the best means of obtaining what this knowledge would give whatever is most conducive to its welfare. The growth and preparation of food, in short, every process on which the comforts of life, and the manual performances of man are dependant, can improve only with our knowledge of those bodies which are the instruments we must use to minister to our wants.

To trace in a regular manner the history of chemistry, though a task not devoid of interest, would contribute nothing to the elucidation of the principles of science. We shall therefore confine ourselves to such remarks of an historical nature as incidentally occur, and proceed immediately to useful details. 1. We shall shortly advert to the nomenclature of chemists, or the language which they use to designate the chemical state or differences of substances; 2, treat of that power of attraction between the particles of bodies upon which chemical changes depend; 3, give a general view of the implements and manipulations of the laboratory, by which the action of this attraction is modified; 4, enter upon the consideration of light and caloric, those unconfinable powers which so many of these manipulations elicit or require; 5, treat of simple substances in general, and from simple substances proceed to those which are compounded.

CHEMICAL NOMENCLATURE.

From the revival of learning after the fall of the Roman empire, to nearly the close of the seventeenth century, Chemistry had been chiefly confined to those who followed it with alchemical views. These persons, many of whom knew that they were deceiving their patrons while others were desirous to conceal their self-delusion, or to create admiration, by the appearance of having done much, were anxious to give every product of their laboratories a mysterious, extraordinary or unintelligible name; as they did not act in concert, the same preparation obtained very different names; and as they were, with few exceptions, as eminent for ignorance as effrontery, and carried on their operations at random, they examined but superficially the substances which they undertook to denominate, and knew not to what they were indebted for their leading properties. Such names, as *horn moon*, *mercury of life*, the *wonderful salt*, the *salt with many virtues*, are a specimen of names equally inappropriate and ridiculous. Hence, when the dreams of alchemy were broken by the dawn of a more enlightened day; when men who had the promulgation of truth only for their object, became chemists, from a persuasion of the advantages which the cultivation of that science would afford to mankind; they found it difficult to unravel the confusion which the misnomers of their predecessors had created. In proportion as discoveries were multiplied, the want of a regular and appropriate nomenclature increased, and formed a strong bar to the general diffusion of a taste for chemical researches. A few trivial innovations which were made by single individuals, in order to accommodate the language of chemistry to the improved state of knowledge, served only to show how much was still wanted. It is perfectly obvious, that names founded upon a mistaken view of the properties of things, tend to the propagation of erroneous opinions; and that when a vast number of substances are designated at random, without any connexion in name, although nearly related in composition, the mere effort of memory to recollect these names

will exceed the effort which ought to be required for the acquisition of science. Towards the close of the last century, therefore, several eminent French chemists determined to take a comprehensive view of the subject, and to remodel the whole system of chemical nomenclature, a task which they completed in 1787. Their object was to reject all the old names which conveyed false ideas, but to preserve those which were not of this class, and to which custom had given a currency scarcely, and not usefully to be checked; they at the same time introduced new terms of appropriate derivation; and the method of forming compound terms, so as to indicate the composition of compound bodies, was pointed out. This system of nomenclature possessed so much merit, that the adoption of it soon became general in France, and from thence it spread with great rapidity to other countries, where it was received either entirely, or with such improvements as experience warranted.—The objections which have been urged against it are futile; they have chiefly amounted to this, that it is not absolutely perfect, and will, by the progress of discovery, hereafter require to be modified. On the contrary, a high eulogium on its value and opportune establishment, is conveyed by the opinion of several eminent chemists, that the present state of chemistry could not be delineated by the language previously in use

Our limits preclude the possibility of inserting a table of chemical terms in this place; but where opportunities occur, we will give the necessary explanations, as each subject gives occasion.

CHEMICAL ATTRACTION OR AFFINITY.

Of all the species of attraction, that of gravitation is the most general and uniform. As far as human investigation extends, it appears to be exerted on every equal particle of matter in an equal degree, and consequently upon all aggregates, in exact proportion to the quantity of matter they contain. Its action also prevails at all distances, and is entirely independent of the state or nature of materials.

The attraction of cohesion, on the contrary, takes place only in minute distances; it differs greatly in degree between different substances, and between some substances it is not exerted at all. The solidity or hardness of substances is supposed to depend upon the strength of the attraction of cohesion between their particles, because the stronger this is, the more it opposes the disunity of the body. This species of attraction is often called the *attraction of aggregation*, because it simply tends to unite the particles of the same or different bodies into a mass, without any power to render the mass homogeneous.—Capillary attraction is merely a branch of the attraction of cohesion.

Magnetic attraction is of a very partial nature; it is exerted only upon a very few substances, and by these substances only on each other.

All bodies are capable of exerting electrical attraction, but they must, in the first place, according to the view which the present state of knowledge affords of the subject, be either over or under saturated with a principle called the electric fluid.

It is uncertain whether all these kinds of attraction result from principles essentially different, or are different modifications of the same cause.

The species of attraction, called *chemical attraction*, is also designated by the appellation of *chemical affinity*.—This kind of attraction takes place only between the elementary particles of different bodies; and every integrant part of the compound which results from its effects, differs in its properties from any of its component parts. It is by this change of properties, that chemical combination, or the action of chemical attraction is distinguished from mere mechanical mixture.

' Whatever relation the attraction of gravitation may have to the attraction of cohesion, the attraction of cohesion appears to be nearly related to chemical attraction, which appears only to be a refined degree of it, and the electric fluid performs an important part in creating the difference.

CHEMICAL UTENSILS AND OPERATIONS.

Of these utensils we can do little more than give their names in this place.

Crucibles and *Cupels* are the vessels commonly employed to contain the bodies submitted to the action of artificial heat. Crucibles are employed in the melting of metals and other operations of fusion. For low heats they are made of earthenware or porcelain, but for strong heats, of clay and sand. Cupels are formed of bone-ashes, with a small quantity of clay and plumbago in powder.

Retorts are globular vessels, formed with a long neck, and are made of earthenware, glass, or metal, according to the use for which they are designed. They are used in distillation.

Alembics.—The alembic is used for distillation, when the products are of too volatile a nature for the use of the retort.

Receivers.—A receiver or recipient is a vessel, usually of glass, in small operations, for receiving the volatile product from a retort or alembic. They are made of a globular form.

Evaporating Vessels are made of wood, glass, metal, porcelain, or Wedgewood's ware. They are generally in the form of shallow basins.

The *Pneumati-chemical Apparatus* is a vessel containing a narrow shelf at the distance of three or four inches from its upper edge, and filled with water till the shelf is covered to the depth of an inch at least. The shelf is perforated with a number of small holes, to which funnels are adapted. When any permanently elastic gas is the product of distillation, and it is desired to fill receivers with the gas, without admitting the admixture of atmospheric air, this apparatus is used.

The *Gasometer* is constructed for the retention of gas, and for facilitating the drawing of it off as it is wanted.

Furnaces are of two kinds, viz., blast-furnaces and wind-furnaces, which are again subdivided into species, and distinguished generally according to the use which is made of them. Blast-furnaces are urged by the

air, forcibly driven from bellows or cylinders; wind-furnaces by the draught of air arising from atmospheric pressure.

The *Blow-Pipe* is a brass tube, by which the flame of a lamp or candle may be directed upon any substance to be operated upon.

The *Thermometer* is a well-known instrument, for measuring the actual or relative temperature of bodies.

The list of chemical apparatus might easily be enlarged, but it will be more advantageous to combine the description of apparatus of less general application to the occasion for their use. Yet there are some articles which appear entitled to ennumeration It will be evident that in a place where all kinds of mechanical operations are constantly resorted to, that a large strong bench will be of considerable importance. Convenient small tables should also be at hand, for supporting mortars, an anvil, &c. A large vice is also a machine of great utility, and the use of it also implies that of hammers, rasps, files, saws, and other implements for working wood and metals.

Mortars, with their pestles, are made of iron for coarse purposes; for other occasions they are made of glass, Wedgewood's ware, and agate. Levigating stones are best made of porphyry. With the mortar and levigating stone, a spring-knife is useful.

Rods of glass, or porcelain, or even clean straws, are used for stirring mixtures. Glass and metal spatulas should also have their place. It is proper to have a pair of bellows; shovels, tongs, pokers, for managing the fire are of course necessary; and tongs of different shapes, for taking out crucibles, &c. from the furnace, should also be at hand.

A plentiful supply of water, fuel, and other things of constant necessity, need scarcely be alluded to.

CLASSIFICATION OF SUBSTANCES.

All the substances in nature, when classed according to their apparent or sensible properties, may be considered either as solid, fluid, aeriform, or etherial. But they may be distinguished by any of these characters, and yet be either simple or compound; to follow, therefore, such a mode of classification would not suit our purpose, as it would introduce confusion by separating the consideration of substances so closely allied as to be almost identical. We shall therefore adopt the more general division of bodies into simple and compound, commencing with those which deviate the furthest from the solid state.

The arrangement we have proposed, introduces the following classification of

SIMPLE SUBSTANCES.

Ethereal.

Light .... Caloric (heat).

Aëriform.

Oxygen.

Aëriform and Combustible.

Nitrogen .... Hydrogen.

Concrete and Combustible.

Carbon .... Phosphorus.
Sulphur .... All the Metals.

Light and Caloric.—The properties of these have already been fully discussed in a preceding part of this work.

Oxygen is the name given to the solid particles of oxygen gas, which is a combination of oxygen, caloric, and light, and is the simplest form in which oxygen can be obtained. Oxygen is called the radical or base of the gas; and the same mode of expression is used in other cases. It is invisible, perfectly elastic like common air, and possesses neither taste nor smell.

Nitrogen.—Atmospherical air, after its vital qualities have been exhausted by combustion or respiration, leaves

a residuum, which is elastic and invisible like itself, but wholly incapable of supporting life or fire. This is nitrogen gas, which is most easily described by including some of its negative qualities; it has no taste, it neither reddens vegetables, blue colours, nor precipitates lime-water; it is not absorbed by water. It unites to oxygen in several proportions; it also unites to hydrogen.

Hydrogen.—This gas has long been generally known by the name of inflammable air; it is the gas which miners call the fire-damp.

Carbon.—Vegetables when burnt leave a black, brittle, and cinerous residuum, which constitutes the greater part of the woody fibre, and is called *charcoal.* Charcoal contains a portion of earthy and saline matters, but when entirely freed from these and other impurities, a solid simple combustible substance remains, which is called *carbon.*

Sulphur, or brimstone, is a well-known substance of a yellow colour, brittle, moderately hard, devoid of smell, but not entirely so of taste.

Phosphorus is a yellowish transparent substance, of the consistence of wax. It is luminous in the dark at common temperatures. It is preserved by keeping it in water; the water has, however, the effect of rendering it opaque, and even exposure to light alters it in some degree.

Metals.—The metals, from their extensive and diversified utility, are amongst the most interesting classes of substances existing. They are supposed to be simple bodies, and not a single fact has ever been ascertained which shows that they can be converted into each other; yet to accomplish this, alchemists exhausted their estates and their lives. The metals are distinguished by their possessing all or the greater part of the following properties:—hardness, tenacity, lustre, opacity, fusibility, mallability, and ductility; and they are excellent conductors of caloric, electricity, and galvanism.

COMPOUND SUBSTANCES.

Alkalies are possessed of the following properties: 1, They are soluble in water; 2, they have an acrid and urinous taste; 3, they are incombustible; 4, they change most vegetable-blues to green; and the yellow to a brown; 5, they form neutral salts with acids; 6, they render oils miscible with water. The alkalies are three in number, *potass*, *soda*, and *ammonia*. Potass and soda are called fixed alkalies, because they are not volatilized, except by an intense heat; ammonia is called the *volatile* alkali, because it is converted into gas at a moderate heat. Oxygen is a component part of all the alkalies, and appears clearly in the case of the two fixed alkalies at least, to be alkalizing principle. The basis of the alkalies are metals.

Acids possess most or all of the following properties: 1, they excite the sensation called *sourness* or *acidity*; 2, they change the blue, green and purple juicies of vegetables to red; 3, they combine with alkalies, earths and metallic oxides, with which they form the compounds called salts; 4, they combine with water in all proportions.

The number of acids which have been discovered, amount to thirty-seven, and are usually classed according to the substances from which they are derived, viz. Mineral acids, 9; Metallic acids, 7; Vegetable acids, 11; and Animal acids, 10.

Oxides.—When the oxygen united to any of the simple substances does not give it the properties of an acid or an alkali, the compound is called an oxide. Most of the metals are capable of combining with different proportions of oxygen, and a difference in the proportion of oxygen gives a different colour to the oxide. Oxides are in general friable or pulverulent, and have the appearance of earths, but one of them is a fluid, and some of them are gases; there are six oxides, viz.—Oxide of Nitrogen, Oxide of Hydrogen, Carbonic oxide, Oxide of Sulphur, Oxide of Phosphorus, and Metallic oxides.

Earths.—The rocks, stones, and mould, which con-

stitute the bulk of the globe, are found, upon being chemically examined, to consist of a few substances which are distinctly different from each other, though they have several properties in common. These substances are called earths.

1. Earths are incombustible, and when alone are scarcely alterable by the most intense heat.

2. They are either insoluble or very sparingly soluble in water or alcohol; when in combination with carbonic acid they are insoluble.

3. Their specific gravity is never five times greater than that of water.

4. They assume the form of a white dry powder when pure.

5. They have little taste or smell, at least when combined with carbonic acid.

6. They are not precipitated from their solutions in acids, by the prussiate of potass, like metallic oxides.

The distinct earths are the nine following Alumine, Silex, Magnesia, Zircon, Glucine, Yttria, Lime, Barytes, and Strontian. The three last named earths having, when pure, a caustic taste, solubility in water, and the effect of changing blue vegetable tinctures to a green, are often called *alkaline earths* and have sometimes been classed among the alkaline; but as they are infusible, and form insoluble compounds with carbonic acid, they certainly have a nearer relation to the general properties of the earths than to the alkalies.

STONES OR FOSSILS.

The whole of the rocks stones and mould, which form so large a portion of our globe, so far as they have been examined, appear, as before observed, to have for their bases one or more of the nine preceding earths, in different states of combination. To the eye, and in properties apparent to the senses, the variety which surrounds us seems infinite; we know very little of the processes which nature has employed to produce this variety; but

the more skilful we become in chemical analysis, the more clearly we perceive that the elements of all things are few in number. We will enumerate the leading varieties of fossils.

Aluminous Fossils.—Aluminous or argillaceous stônes are very abundant; with some rare exceptions, they are all soft enough to be cut with a knife, and they do not, like aluminous earths, fall to powder by mere immersion in water. They are six in number, viz.:—Corundum, Hornstone, Basaltes, Mica, Schistus, and Zeolites.

Siliceous Fossils strike fire with steel, and they are generally susceptible of a fine polish; a great number of gems belong to this class. They are seven in number, viz.:—Quartz or Rock Crystal, Feldspar, Flints, Agates, Lapis Lazuli, Schorl, and Granite.

Magnesian Fossils are those which derive their character from magnesia, though they do not all contain a great proportion of this earth; they are distinguished by being greasy to the touch, and have neither the hardness nor infusibility of siliceous fossils. They consist of four, viz.:—Talc, Steatites, Serpentine, and Asbestos

•*Calcareous Fossils* are generally harder than the magnesian, but not so hard as the siliceous; none of them strike fire with steel; some of them imbibe water, and crumble by exposure to frost; others become harder by the same exposure. They comprise five kinds, viz.:—Crystalized Calcareous Stones, Marble, Stalactites, Gypsum, and Fluor Spar.

SALTS.

The compound formed by the combination of an acid with an alkali, an earth, or a metallic oxide, is called a *salt.*

The term neutral salt was formerly given to all combinations of acids and alkalies, but the epithet neutral is now restricted to those salts in which the acid and the alkali completely saturate each other, and in which,

therefore the peculiar properties of neither can be detected.

The salts form a numerous class of bodies. Fourcroy reckons that there are one hundred and thirty-four species, and the number belonging to each species is often considerable. There can scarcely be less than two thousand distinct salts; but we shall only notice some of the most useful.

Sulphates, of which there are six, viz.:—Sulphate of Allumine, Ammonia, Sulphate of Soda, Green Sulphate of Iron, Red Sulphate of Iron, and Sulphate of Copper,—are in general crystalizable, have some taste, but no smell; are precipitated by solution of barytes, and afford sulphurets when heated red-hot with charcoal

Nitrates, viz:—Nitrate of Potass, Nitrate of Soda, and Nitrate of Ammonia,—are soluble in water, and crystalizable; they deflagrate violently when heated to redness with charcoal, or other combustibles; sulphuric acid disengages from them a white vapour of nitric acid. By heat they are decomposed, and yield at first a considerable quantity of oxygen gas.

Muriates.—Muriate of Soda, of Potass, of Ammonia, and Hyper-oxymuriate of Potass, are the most volatile of all salts. They are at the same time the least decomposible; they may be melted and volatilized without undergoing decomposition. They effervesce with sulphuric acid, and white acrid fumes of muriatic acid are disengaged.

Carbonates—Sub-carbonates of Potass and Soda, and Carbonate of Lime, effervese, and yield carbonic acid, when sulphuric or nitric acid is poured upon them; all the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble.

Huates of Lime, and of Sil-x, are not decomposed by heat, nor altered by combustibles; when sulphuric acid is poured upon them they yield acrid vapours of fluoric acid, which corrodes glass.

Borates are all fusible into glass and assist the fusion of other bodies, particularly metals. The principal salts of this class are the sub-borate of soda, the borate of potass, of lime, of magnesia, and of alumine.

Acetates ot Potass, of Ammonia, of Lead, and of Copper, are distinguished by their great solubility in water; by

the decomposition of the acid when the solution is exposed to the air; by their being decomposed by heat, and by their yielding acid when mixed with sulphuric acid, and distilled.

Tartrates are decomposed by a red heat. The earthy tartrates are less soluble than the alkaline: but they are all capable of combining with another base, and forming triple salts.

The principle tartrates are those of potass, potass and soda of potass and ammonia, of lime, of strontian, and of potass and antimony.

Phosphates are capable of vitrification; are partially decomposed by sulphuric acid; are phosphorescent at a high temperature; are soluble in nitric acid without effervescence: and may be precipitated from their solutions by lime water. The principal phosphates are those of potass, of soda, of ammonia of lime, of alumine, and of magnesia.

Prussiates.—The singular affinities of some of the prussiates render them interesting to the chemist; the simple prussiates, are, however, little regarded, because destitute of permanency, being decomposed merely by exposure to the air, unless united with a metallic oxide. The prussic acid does not appear capable of saturating an alkali; and the weakest acid known is capable of decomposing the prussiates of the earths and alkalies. The most important of the prussiates is that of iron; and of the triple prussiates those of potass, soda, lime, or ammonia with iron.

ORGANIC SUBSTANCES.

Vegetables, though infinitely diversified in their appearance and properties, are found to consist of a small number of simple substances; carbon is the basis of them all, and after carbon, hydrogen and oxygen may be considered as forming the principal parts of them. Some vegetables contain nitrogen, others phosphorus, earths and metals, but these elements are not general; they

belong only to particular plants, or to plants in particular situations.

Plants derive a principal part of their nourishment from water; their roots imbibe the water, which is decomposed in them by the assistance of light and heat, and a part of its hydrogen becomes fixed, while part at least of the oxygen is given out by transpiration.

The processes of vegetation have a considerable tendency to produce equality of temperature. If the bulb of a thermometer be plunged into a hole in a tree, it indicates a higher temperature than the atmosphere in cold weather, and a lower temperature in hot weather.

Animal Substances present us with the same constituent principles as vegetables; but the proportions of these principles are different. By destructive distillation they afford much ammonia, which is sparingly distributed in the vegetable kingdom; they also contain much nitrogen, of which the proportion is usually small among vegetables; and they are more abundant in phosphorus, while of carbon and hydrogen, which are abundant in vegetables, they contain but little. They are alo distinguished from vegetables by their undergoing only the putrid fermentation, while vegetables undergo one fermentation of which the product affords alcohol, and another which affords vinegar. The distinct compound substances derived from animals are very numerous.

Fermentation — When vegetables and animals are deprived of life, the elements of which they are composed exert an action on each other; some of them enter into new combinations, others become entirely undecompounded; and the identity of the original substance is destroyed.

Fermentation is of three kinds: 1. the *vinous;* 2, the *acetous;* 3, the *putrid*. The two first kinds are peculiar to vegetable substances; the last is common both to vegetable and animal substances; though the change it indicates, is, in reference to animal substances, more generally called putrefaction.

Alcohol, or the purely spirituous part of liquors which have undergone the vinous fermentation and no other, is transparent and colourless like water; its taste is highly pungent, but agreeable. It is extremely inflammable, and when set on fire it leaves no residuum. It is, from its

being converted into vapour much sooner than water, that it is easily separated by distillation from wine, beer, and other liquors which contain it. All these liquors owe their strength to the quantity of alcohol they contain: the best port wine contains about one fourth of its bulk of alcohol. Brandy, rum, and whisky contain still more. Proof spirit is half water and half alcohol.

Ether.—If alcohol be mixed with its own weight of sulphuric acid, gradually added to prevent explosion, and the mixture be distilled in a sand-bath, the first product obtained is alcohol, but afterwards a very different fluid, which is equal in quantity to half the alcohol employed. This fluid is called *ether*, which is still more inflammable and volatile than alcohol, and equally as colourless. It is the lightest of all known fluids; its smell is fragrant and agreeable, but not powerful. Its taste is hot and pungent. Its combustion yields a blue flame, and rather more smoke than alcohol. Its internal use extends to all spasmodic affections; and it has latterly been applied in sufficient quantity to patients to deprive them of all sensation, and while in this state operations of a dangerous nature, such as amputations, have been successfully conducted. But this experiment ought never to be attempted but by practical men of experience; as several deaths have occurred through its improper application.

CHEMICAL EXPERIMENTS.

1. To determine the specific gravity of solids, fill a phial with water, and mark the weight of the whole accurately, in grains. Now weigh 100 grains of the substance to be examined, and drop it graduallly into the water, in the phial. The difference in weight of the bottle with its contents now, and when it was filled only with water, will determine the specific gravity of the substance under examination. For example, if the bottle weighs 40 grains more than when it was filled with water only, it shows that 100 grains of the mineral displace.

only 60 grains of the water; and consequently, that it is of nearly twice the specific gravity of water.

2. Invert a clean dry glass tumbler over a hand basin nearly full of water and when the rim is brought parallel with the surface, plunge it perpendicularly downwards. It may now be observed that the water has risen considerably in the basin; this rising is owing to the displacement by the glass of a volume of water equal to its own bulk; consequently no water can be within the tumbler. For if the inverted tumbler was filled with water, of course no greater rise could be observed in the basin than what would be caused by the solid bulk of the glass immersed in it. The reason that no water ascends in the glass is, that previous to its immersion, it was filled with air, which pressing upon the water below, prevents its ascent. Another proof that no water has entered the glass is, that the inside will be found perfectly dry.

This experiment may be rendered more interesting by inverting the tumbler over a piece of cork, or wood, floating over the surface of the water. The cork, or wood, instead of remaining on a level with the surface of the water outside the glass, will be seen at the bottom of the basin. After the experiment is concluded, the upper part of the wood will be found quite dry.

3. Put a piece of lighted paper on the surface of water in a basin, and invert over it a tumbler, as in the former experiment. The water, instead of being displaced, will rush up into the glass, and will continue to do so as long as the combustible substance continues burning.

4. If we pour four liquors of different specific gravities into a glass vessel, they will remain separate and distinct from each other. For example, if we take mercury, oil of tartar, alcohol, and oil of turpentine; shake them in a glass, and let them settle a few minutes; each will return to its proper situation, viz., the mercury at the bottom, the oil of tartar next, then the alcohol, and above all, the oil of turpentine.

Test for Alum in Bread.—On macerating a small piece of new-baked bread in cold water, sufficient to dissolve it, the taste of the latter, if alum has been used by the baker, will acquire a sweet astringency; or a heated knife may be thrust into a loaf before it has grown cold, and if it be free from that ingredient, scarcely any altera-

tion will be seen on the blade; but if alum has been used, the blade, after being allowed to cool, will appear slightly covered with an aluminous substance.

To make Phosphoric Oil—Put one part of phosphorus into six of olive oil, and digest them by a sand-heat. The phosphorus will dissolve. It must be kept well corked. This oil has the property of being luminous in the dark, but has not sufficient heat to burn. If rubbed on the face and hands, (taking care to shut the eyes,) the appearance will be most hideously frightful; all the parts which have been rubbed appearing to be covered by a luminous lambent flame of a bluish colour, whilst the eyes and mouth appear like black spots. No danger attends this experiment.

Luminous Characters on Walls—Take a piece of phosphorus, and, during candle-light, write upon a white-washed wall any sentence or word; or draw upon the same any figure according to fancy. Withdraw the light, and whatever parts the phosphorus has touched will appear quite luminous, emitting a whitish smoke, or vapour.

This experiment should not be performed before timid persons, without previous intimation as to the nature of phosphorus.

Combustibility of Hydrogen Gas—If the flame of a candle be brought in contact with a stream of hydrogen gas, rushing out at a stop-cock attached to a bladder, or jar, charged with it, a beautiful combustion will take place, accompanied by a fine yellowish flame, which may be lengthened to six or eight inches, by pressing the gas out of the bladder.

Fill a bladder, (having a stop-cock or tobacco-pipe attached,) with hydrogen-gas, and having prepared a lather of yellow soap, immerse the bowl of the pipe in it. Then press the bladder so as to form a globe or bubble in the lather, and as it ascends, inflame it by means of a lighted candle. The bubble will explode with a vivid flash: the whole of the gas may be thus expended in successive bubbles and flashes.

Hydro-Zincic Gas.—Put half an ounce of zinc filings into a common phial, which has a cork perforated to receive a glass tube, or stem of a tobacco-pipe. Pour over the filings half-an-ounce of sulphuric acid, with an

ounce and a half of water. Fit in the cork, and apply a lighted candle to the gas which rushes out; it will immediately inflame, and continue to burn with a blue light as long as the gas is acted on.

If zinc filings are sprinkled on the flame of a candle, they will immediately burn like so much saw-dust. This combustion is very beautiful, for each grain in the course of inflammation, scintillates, and assumes a luminous starry form.

Extemporaneous Preparation of a Saline Carbonated Draught.—Pulverise one ounce of citric-acid, and divide it into twenty-four parts, which are to be put into small blue papers. Pulverise, also, an ounce of the sub-carbonate of soda, and divide it into twenty-four like parts, which put into white paper. When the draught is wanted, put the carbonate into a tumbler half filled with spring water: when this is completely dissolved, add the acid, which will immediately cause an effervescing discharge of carbonic acid. During this effervescence swallow the draught. This is an economic, and a very refreshing drink in warm weather.

A similar preparation may be made by using tartaric acid, instead of the citric.

Test for Lead and Copper in Wine, &c.—A very simple test for these pernicious metals in Wine and Cyder, exists ready formed by nature. Pour into a glass of suspected Wine, Cyder, or Perry, a few drops of Harrogate, or Strathpeffer water. If any lead or copper be present, it will fall down in the state of a black precipitate, being combined with the sulphuretted hydrogen, by which these waters are impregnated.

[Lead is often used by wine-merchants to give an astringency to port wine; that is, that like old port, it may appear rough to the tongue. Sometimes they hang a sheet of lead in the cask; at others, they pour in a solution of sugar of lead, for the purpose of sweetening, as they term it. An extensive wine-merchant in London, acknowledged on his death-bed, that in his long course of business, he had seen numbers of his customers fall victims to their predilection for his wines; and had remarked, that no man ever lived long, who was in the practice of drinking them! Arsenic, is also used, to give

an oily appearance to sherry, madeira, and other pale wines.]

Sympathetic Ink.—If a letter be written with a solution of the sulphate of iron, the writing will be invisible; but, if it be afterwards rubbed over by a feather, dipped in a solution of prussiate of potass, it will appear of a beautiful colour.

Another.—Write on paper with a solution of nitrate of bismuth, and the letters will be invisible; but dip the feather in an infusion of galls, and bring it over the writing it will appear of a brown colour.

If the previous use of sulphate of iron and nitrate of bismuth, in these experiments be concealed from the spectators, great surprise will be excited by the appearance of the writing, merely by the dash of a feather

Aromatic Vinegar for Purifying large Buildings—Take of common vinegar any quantity, mix a sufficient quantity of powdered chalk, or common whitening with it, as long as bubbles of carbonic acid gas arise. Let the white matter subside, and pour off the insipid supernatant liquor, afterwards let the white powder be dried, either in the open air, or by a fire. When dry, pour upon it, in a glass or stone vessel, sulphuric acid, as long as white acid fumes continue to ascend. This product is similar to the acetic acid known amongst apothecaries, by the name of aromatic vinegar. The simplicity of this process points it out as a very useful one, for purifying houses or hospitals when contagion is suspected, the white acid fumes diffusing themselves quickly around.

Artificial Volcano.—Mix twenty-eight pounds of sulphur and twenty-eight pounds of iron filings together, and add as much water as will form the whole into a paste: bury the mass about two feet below the surface of the earth; and in twelve or fourteen hours so much heat will be generated as to swell the earth, and cause an artificial volcano, throwing up whatever impedes its progress, and throwing around ashes of a yellow and black colour. To succeed in this experiment, advantage should be taken of the warm weather (in the months of June, July, or August), and after the tenth hour of burying the mass, great care must be taken not to approach too near its situation. The experiment might be more

safely tried with one half of the above quantities of sulphur and iron filings, buried about one foot.

PHYSIOGNOMY AND CRANIOLOGY.

ALTHOUGH we may not have much historical matter to adduce upon these sciences, we think it proper to give the principles upon which the chief supporters of them have acted, and which they pronounce to be clear and definite. The first named, *physiognomy*, claims an ancient and high descent, even as remote as the period of Aristotle and Admantius, who have both written upon it. The most eminent writers who have since discussed these subjects are Porta, Hudd, Gall, Campar, Kent, Lavater, and Blumenbach. The hero of late physiognomical writers is *Lavater*, and of its sister science, Craniology, Professor *Gall* of Vienna, the inventor.

The term *physiognomy*, which is the first of the two subjects we now treat upon, is derived from a Greek compound, signifying, *nature*, and *I know*. Physiognomy refers to the surface of the head; and Craniology goes to its basis, or interior. The sciences suffer the fate of most newly adopted discoveries, not being sufficiently identified by popular belief. Like the doctrine of Harvey, the illustrious discoverer of the circulation of the blood, they are reviled, misstated, and vilified, as was that valuable discovery in the time of Harvey; and for years after his death, the college of physicians and surgeons, previous to their admission of new members, compelled them to swear solemnly, that they *did not believe in the circulation of the blood!* and treated as merely visionary, and their supporters derided with the sneers and abuse of the would-be scientific world. In the present state of public opinion, we do not mean to impose our belief as the criterion of truth; nor do we wish to place obstacles in the way to the perfection of those sciences, of which

their supporters appear to be firmly persuaded of their evident existence; but, on the contray, advise an impartial investigation. All we can do, shall be done without prejudice, which is impartially to state the evidence of their professors in their favour, with such ostensible arguments that have been urged against them, and leave the reader to form his own opinion. Having done this, we hope to discharge our duty to science, and not be found wanting in that respect we feel towards a liberal minded and enlightened public.

The supporters of physiognomy state in the first place, that they regard the human face as the *index* of the mind; they add that it bears an evident analogy to the dial-plate of a time-piece: whilst the feelings which operate on the mind, give impulses to the will, and direct the corporeal motion of the frame, they say these are to be considered as the mechanism in the interior of a clock which directs the finger to the hour: by a frequent repetition of our feelings, they aver, the features acquire a habitude to evidence certain expressions in the countenance, superior to all other feelings, impressing the face with an unfailing index to the prevailing temperament of the mind. This statement appears to be extremely probable and very natural. Insomuch, that an early physiognomist being introduced to Socrates, without knowing his name, or being at all acquainted with the virtues which distinguished that excellent individual, was asked to give the company his opinion of the physiognomy of that philosopher. With a simplicity natural to the age in which he lived, which was distinguished for truth, he informed them that the person of whom his opinion was requested was naturally addicted to every vice which can be said to disgrace the human character, enumerating them at the same time: on this the whole company burst into derision on the absurdity of the pretended science, and laughed at its professor;' but not so the philosopher, who was the cause of their present mirth; he desired them to suspend their judgment till he would inform them that "he was indeed by nature inclined to those vices the physiognomist had mentioned; but that he had conquered these natural feelings, and subdued those affections by the practice of reason and philosophy." Here is a fact

well known to the majority of the opponents to the science of physiognomy, yet they have industriously kept it in the back-ground to favour their own sophistry. But for the benefit of our readers who may not be perfectly versed in the ancient authors, we can inform them that this circumstance is mentioned by Xenophon, in his life of Socrates,—a work which has never been contradicted by our most eminent historians—and if such is the fact, of which we can have no doubt, it must give a strong impulse in favour of physiognomy as a true science.

From this little deviation we will return. It has been said, that by the frequent acts of any favourite propensity, affection, or passion, impressed by natural temperament, or dragged by custom into the habits of an individual, the countenance is often put in a posture which attends such affections or actions, in consequence of a passage forced by the animal spirits through the nerves, in which the essence of a habit consists; as those Indians devoted to religion are said to distort their limbs by long sitting or standing in any peculiar position; or, at least, it falls insensibly, and, as it were mechanically, into some certain and settled position, directed by some mental temperament, unless when under the influence of a stronger and contrary passion, or concealed by the flexibility of disguise and design. Observation has frequently confirmed this position; and we may here add, that so apparent are certain inclinations of the mind in various individuals, that we cannot well be mistaken in estimating character; indeed, in this respect, an animal, some say a dog, but we, upon our veracity can vouch for a *cat*, has sagacity enough to discover, not only the disposition of its master, but also to appreciate the character of certain strangers to a given extent.

Our opinion is, decidedly, that the supporters of this science ought to divide it into two distinct branches: in the first should be classed such characteristic traits which proclaim fixed and certain dispositions, generated like those defined in the preceding paragraph, as founded upon mere principles of *habit*, and fixed in the physiognomy of the face: and *secondly*, those where the expressions are *transient*, and are the indice to certain local dispositions of the mind; so as from one expression to draw a proba-

ble conclusion of its successor, and of those thoughts which, at that instant, occupy the mind of the individual.

The science of man, in respect to his exterior appearance, is certainly influenced by a great variety of causes, much too numerons for us to investigate in this little volume, where we have so many subjects to treat of, as an introduction for our young friends into the arcana of science; yet we will not hesitate to point out some few particulars of national characteristics—the *climate, soil, atmosphere, provisions, habits*, with several local *et ceteras*, which should be distinctly considered. Agreeable to this idea, a distinguished professor, while writing on this subject, has divided the vast mass of humanity into *four* distinct classes, which, for the sake of brevity, we will thus enumerate:—1st, Whites; 2nd, Negroes; 3rd, Huns, Moguls, or Calmucs; and 4th, Hindoos, or the natives of Hindostan.

The opposers of this science, say, and probably with justice, that circumstances purely external, and which may be accidental, cannot be the original causes of what is assimulated or inherited. It is readily conceded those events they enumerate are not the original cause, but as they occur, they assist that cause in the performance of certain effects, to which they also communicate a peculiarity of character. "As well," they continue, "could chance produce a body perfectly organized." The professor alluded to proceeds by observing, that "man was undoubtedly intended to be the inhabitant of all soils. Hence the fact that many internal propensities must be latent in him, which shall remain inactive, or be put in motion according to his situation on the earth, so that in progressive generations, he shall appear as if born for the particular soil in which he seems planted."

It is this gentleman's opinion, "that the air and sun are the two chief causes which influence the operations of generative propagation, which give a lasting developement of germ, and the chief propensities to the individual." The opponents to physiology remark, "or in other words the above powers may be the origin of a new race." We can answer for the professor, that he had no hyperbolical idea in contemplation. He goes on to say—"Food may produce some slight variations; these,

however, after emigration, must soon disappear, and cease their operations, as well on the source of life as on that of animal conformation and motion." It has been also observed, that the nearer man approaches to the frigid zone, the more is he reduced in stature. This appears certainly as a natural consequence of that situation; because independent of its being the very physical nature of cold to shorten and depress, as is invariably found to be the case, as is to be observed in the figure of the earth itself. But independent of this, the economy of nature appears to have conformed to this circumstance, in rendering the human stature shorter the nearer it approaches the pole, and for this evident reason:—the expanding power of the heart to force the blood to the extremities, must have been of necessity increased; as it is in this action of the vital liquid the heat of the frame consists. If this circulating medium was not duly impelled through the frame, the members left without its benefit would become chill and totally useless, but the Divine Creator ordered the economy of the frame in those parts to be constructed upon a different principle:—the stature has been shortened, to confine the operation of the circulation to the trunk, where natural heat accumulating, the whole body has a greater proportion of the comfortable sensation of animal heat; the very reverse of which is so sensibly felt by strangers visiting that country.

The enormous, and, as some think, disgusting lips of the African negro is attributed, by the Abbe Winckelman, to the heat of the climate they inhabit. Others account for the blackness of their skin, from supposing the excess of particles of iron in their blood (now well known by analysis to constitute a portion of the blood of every human being) which causes its sanguine colour in all men, but is conceived to be necessary in negroes, to support their frames under the oppressive heat which they are forced to endure; this is supposed to be the cause of their dark complexion, as well as the evaporation of those acidities which smell so strong in that race of people.

In pointing out the principal traits which distinguish the nations of different regions, Lavater observes, that a person deeply enamoured of another, and thinking much on the form and position of the features, might, in process of time assume a resemblance of the beloved object,

though thousands of miles might intervene between them; and pursuing this idea, he adds—"that it is equally possible an individual meditating revenge, may compose his countenance into a likeness of his victim." If this last sentence had not been in his own words, we might have been inclined to consider it as an interpolation of some of his opponents; but the words are his own, and therefore we are at a loss how he could reconcile it with the previous sentence. Unfortunately we have two cases at this present day in which I am writing (April 22, 1849), to show the fallacy of this reasoning of Lavater, highly as we esteem him: the first of these is James Bloomfield Rush, who suffered the extreme penalty of the law for the murder of a father and son, upon both of whom he had for many years meditated his hellish project, for the purpose of making himself the proprietor of their property, by means of forged documents, which, after their death, there would be no person left to contradict his right to the property he had so long schemed to obtain. We are of opinion that if Lavater had lived in our time, the case of Rush would have caused him to correct his mistake. But the second case to which we allude is that of the monster in human shape, known throughout Europe by the name of John Gleeson Wilson, who is at the present moment in prison under the committal of the coroner and magistrates, for the barbarous murder of two innocent women and two children in the borough of Liverpool. The circumstances of this last atrocious deed must be fresh in the remembrance of every individual; and it is only mentioned here to state, that there could not be a better subject presented to a physiognomist,—without affectation, I declare that I could have marked that wretch, if I had seen him previous to the deed, as I had the good fortune to get a view of him within a very few days after. But be that as it may, the total incorrectness of Lavater's fancy may be exposed by merely observing that the person under the influence of the passion of revenge, must bear in his countenance, the strong lines of expression of that restless and diabolical affection. Let us suppose, that the person intended to be injured is unconscious of the secret machinations against him, he may at the instant be engaged in some benevolent pursuit, or may feel some inward joy, which moulds his features into

an expression just the reverse of his adversary, who may generally have seen him thus: for revenge is frequently aimed at the best of men; consequently, the countenance of a fiend cannot at the same time beam with complacency, or form a set of features where the soul is in equanimity.

That Lavater was an enthusiastic theorist, we willingly admit; and also concede that we do not believe him sufficiently philosophical in every case; but surely the weakness, infirmity, or impetuosity of a judge does not invalidate the system of jurisprudence over which he presides.—that his feelings were amiable is not denied; that he was liable to err, is what is to be expected of every human agent. But with all his failings we cannot but admire his partiality to our countrymen, where if his judgment is not always correct, he certainly appears to appreciate their general character with truth, as we shall presently observe, where he speaks of the physiognomical resemblance of the inhabitants of various nations.

First, he asserts—That each creature is indispensable in the vast compass of the creation; but each individual is not alike informed of the truth of this fact,—as man only is conscious that his own place cannot be supplied by another. The idea thus conceived he thinks one of the best and most fortunate consequences to physiognomy; and contends that the most deformed and wicked persons are still superior to the most perfect and beautiful animals; because they have always the power to amend, and in some degree to restore themselves to the place assigned them in the creation; and however their features may be distorted by the indulgence of their passions, still the image of their Creator remains from which *sin* is only to be expelled, to render the likeness still nearer perfection." In making those remarks which are the chief distinguishing traits of various regions, he observes, "that the placing of different persons together, selected from nations remotely situated from each other, gives at one glance their surprising varieties of visage." Yet he acknowledges, that to point out these variations is a task of considerable difficulty: and his assertion that this may be done with more facility from a single individual than the mass of population seems extremely probable. The French he thinks do not possess equally commanding traits with the

English; nor are they so minute as the Germans; and it is to the peculiarity of their teeth and manner of laughing, that he attributed his power of deciding upon their origin. The Italians he appreciated by the form of their noses, diminutive eyes and projecting chins.

The eyebrows and foreheads are the criteria of the people of England. The Dutch possess a peculiar rotundity of the head, and have weak hair; the Germans, numerous angles and wrinkles about the eyes and in the cheeks; and the Russians are remarkable for black and light coloured hair and flat noses.

He considers the natives of England, in the aggregate as the most favoured people upon the earth, with respect to personal beauty; saying they have the best arched forehead, and that only upwards and towards the eyebrows, rectilinear, medullary noses, frequently round, but very seldom pointed, and lips equally large, with the addition of full rounded chins: still greater perfections are attributed to the eyes of the English, which are said to possess the expression of manly strength, generosity, liberality, and frankness; to which apparent indication in the face the eyebrows greatly contribute. With complexions infinitely fairer than the Germans, they have the advantage of escaping the numerous wrinkles found in the face of the latter, and their natural contour is noble and commanding.

Judging from the ladies of England he had seen while in this country, he was led to say, they appeared to him to be wholly composed of nerve and marrow; tall and slender in their forms, gentle, and as distant from coarseness and harshness as earth from heaven! We will supply the picture he left unfinished, and say—Benignity and virtue are their characteristics. In beauty, they are confessed supreme! Here, their face is a certain index of their mind.

His own country women (Switzers) he found to have many varieties. Those in Zurich are found to be generally meagre, and of middle size, and either corpulent or very thin. If we pursue this subject further, we shall find the people of Lapland and parts of Tartary are of a very diminutive stature, savage countenances, flat faces, broad noses, large mouths, thick lips, peaked chins, with eyes yellow-brown, almost approaching to black, and lids

retiring upwards; the grossest manners, and stupid beyond credibility; but of all human varieties the nations of New Holland seem to be the most debased and miserable; tall and slender, to add to deformity, thick lips, large noses, wide mouths, they are taught from infancy to keep their eyes almost shut, to avoid the insects which continually swarm around them.

The more favourable side of this picture of national physiognomy, exhibits the people of Cashmere, Georgians, Circassians, and Mingrellians; neat, noble and formed for admiration, particularly the females, whose charms of person and face are proverbial.

The author from whom these extracts are taken says, "Before we enter upon a description of the marks which according to Lavater point out the character of the possessor, it may be proper to give one or two instances of the fallacy and of the truth of the conclusions drawn from them, in order that our readers may form their own opinions as to the folly or propriety of entertaining a propensity to form a judgment from the shapes of their noses, eyes, foreheads, and chins.

A gentleman informed Lavater, that he once happened to see a criminal condemned to the wheel, who had cruelly murdered his benefactor, and who yet possessed the benevolent and open countenance of an angel of Luido. It is not impossible, adds that gentleman, but that the head of a Regulus might be found among criminals, or of a Vestal in the house of correction. Gavater admits this to its full extent; but his reasoning to reconcile it to his system, is by no means conclusive. We may here observe that provided physiognomy could be reduced to those certain rules upon which sciences proceed and are founded, it would be most useful to mankind generally.

We must, however, acknowledge, when we hear of any criminal action attended with very strong circumstances of individual guilt, the imagination assists us in drawing a picture of the culprit, agreeable to our own ideas of his deformity; and without reflecting that the murderous assassin is marked by no horrible exterior, which would have placed humanity on its guard against his wicked intentions. However upon viewing the culprit, we are, perhaps, surprised to find that there is

nothing in his appearance particularly indicative of cruelty. To complete the outlines of his portrait we then industriously endeavour to discover the latent marks of villany lurking in his eyes, converting the wrinkles of his face into the clues of savage cruelty; disease or age are turned into some horrible expression answering our expectations; and we depart exclaiming against the striking contour of the miserable wretch, when perhaps many of our near friends, or even relatives, would suffer greatly by a comparison, who yet had led uniformly innocent lives. On the other hand it must be confessed, that vice generally stamps her votaries with indelible marks which we cannot mistake at a glance; but this remark can only, perhaps, apply to the confirmed enemies of virtue whose actions are so uniformly vicious that very little propriety occurs in their conduct.

The following anecdote, as related by Lavater, may serve partially to illustrate the above observations, showing that the features, or more correctly, the membraneous ligaments of the face, are affected by the turn of mind; and if that is not one part of the position which the physiognomist means to establish, we are at a loss to know where to find it. An innocent young lady, of high birth, educated in the retirement of the country, happened one evening to be passing a mirror with a candle in her hand, immediately after evening prayers; she had in the other hand a bible, which she laid upon a table; her eye, in passing the glass, showed her her own form; she instantly averted her eyes and retired. A succeeding winter had passed in the amusements and dissipation of a gay metropolis; she happened to pass the same glass in a state of mind forgetful of her former religious impressions; she now conceived her features deprived of that fascinating grace which a serene and happy state of mind inspires: alarmed at the change, she flew to a sofa, ejaculated sentences of penitence, and formed resolutions for future amendment.

Character of the Forehead.—Lavater appears to have been the first who attended to the peculiarities of the position and outlines of the forehead, which he considered the most important part presented for the study of the physiognomist. This he divides into three classes; these he terms *perpendicular*, *projecting*, and *retreating*, each

possessing a number of variations: the principal, however, are rectilinear, half-round, half-rectilinear, flowing into each other; half-round, half-rectilinear, interrupted; curve-lined, simple; the curve-lined, double and triple.

A long forehead denotes much capacity of comprehension and less activity.

Lavater begins his remarks on the face with the forehead. According to him, and experience confirms his remarks, the general form, arch, obliquity, and position of the skull of the forehead, denote degrees of thought, sensibility, mental vigour, and the various propensities and aptitudes of the mind of man; at the same time the skin, bone, wrinkles, &c., explain the state of mind of the individual at the moment of observation, and of the passing impressions which influence it; the shape of the bones affording the internal quantity, and the covering the application of physiognomical power: however the latter may be affected, the bones must remain unaltered, and yet they regulate the wrinkles by variation of their component form. Wrinkles are produced by certain degrees of flatness, others arise from arching; these, considered separately, give the form of the arch, and *vice versa*. some foreheads are furnished with wrinkles that are confined to a horizontal form, some perpendicular, others curved, whilst others consist of confused or mixed lines: those least perplexed when in action are usually distinct; some foreheads are without wrinkles. A short and firm forehead denotes compression, stability, and little volatility; serenity and pertinacity belong to the rectilinear; the more curved than angular portends flexibility and tenderness of character; deficiency of understanding is discoverable in those whose foreheads are perpendicular from the hair to the eyebrows; but the perfectly perpendicular, gently arched at the top, signifies that the possessor thinks coolly and profoundly.* The projecting forehead indicates stupidity and mental weakness; the retreating, quite the reverse; the insular and prominent above, with straight lines below, and nearly perpendicular, shows sensibility, wisdom, and good understanding. The rectilinear oblique forehead has the same properties: as round heads are considered as feminine, with a union of curved and straight lines happily disposed into a similar position of the forehead gives the

character of consummate wisdom. Right lines, considered as such, and curves, considered as such, are relaxed, as power and weakness, obstinacy and flexibility, understanding and sensation. When the bones surrounding the eye project and are sharp, the person thus formed possesses a powerful stimulus to strong mental energy, which is productive of excellent and well-digested plans; and yet this does not seem a peculiar mark of wisdom, as many wise men have been known without it: those thus circumstanced have more firmness when the forehead rests perpendicularly upon horizontal eyebrows, and considerably rounded towards the temples. Perpendicular foreheads, however, which project so as not to rest on the nose, and which are short, small, shine, and are full of wrinkles, give undoubted indications of the weakness of the thinking faculty; perseverance and oppressive violent activity, united with vigour and hastiness, belong to the forehead composed of various confused protuberances; on the other hand, when the profile of this part of the head affords two well proportioned arches, the lowest projecting, it is a certain sign of a good temperament, and a good understanding. All great and excellent men have been found to have their eyebrows finely arched and well defined.

Circumspection followed by stability attends square foreheads, with spacious temples and eye-bones of this description; when perpendicular natural wrinkles appear, they express power of mind and application, but horizontal, interrupted in the middle or broken at the extremities, betray, in general, negligence, if not want of ability.

Deep indenting bones of the forehead, situated between the eye-brows, and extending in a particular direction, mark the happy few who possess generous and noble minds, connected with excellence of understanding; besides a blue *veina frontalis*, in the form of a Y, situated in an arched smooth forehead, is an indication of similar advantages.

The Eye.—The eyes of mankind are composed of various shades of colour, the most common of which are grey mixed with white, grey tinted with blue, and shades of green, orange, and yellow. According to the celebrated naturalist Buffon, the orange and blue are most predominant, and those colours often meet in the

same eye, those generally supposed to be black are not really so, and upon attentive examination they will be found to consist of yellow, a deep orange, a brown, which being instantly opposed to the clear white of the ball, assumes a darkness mistaken for black. The same naturalist observes that shades of yellow, orange, blue, and grey are often visible in the same eye; and when blue, even if the lightest tint appears, it is invariably the predominant colour, and may be found in rays dispersed through the iris; the orange is differently disposed at a trifling distance from the pupil; it is in flakes, and round, but the blue so far overpowers it, that the eye assumes the appearance of being wholly of that colour. The fire and vivacity emitted by the eye cannot be so powerful in those of the lighter tints; it is therefore in the dark ones alone that we look for the emotions of the soul. Quiet and mildness, with a certain degree of archness, are the characteristics of the blue. Some eyes are remarkable for the absence of colour; the iris is faintly shaded with blue or grey, the tints of orange are so light that they are hardly discernible: in eyes thus formed, the black of the pupil appears too conspicuous, and it may be said that portion is alone visible at a little distance, which circumstance gives the person possessing them what is called a ghastly and spectre-like appearance.

There are eyes whose iris may be said to be almost green, but these are uncommon. It would require the pen of an inspired writer to describe the astonishing variety of expression of which the eyes are capable; being situated near the supposed seat of the soul, every sensation of that invisible spirit appears to rush in full vigour from those intelligent organs; all the passions may be seen in them; we shrink from their indication of anger; we find pleasure with all her train of joys dancing in them; we feel their force in love; and melt into tears on observing them suffused in the moisture of grief: in short their language is less deceptive, and more powerful than that of the tongue. The transitions are so rapid in the expression of the eyes, that it requires very close and attentive examination to catch and describe the emotions of the mind visible in them. Admitting this fact, it will appear that the physiognomist is liable to numerous and egregious errors in drawing his conclusions from them. Paracelsus, a man of strong genius, and like Lavater,

misguided in many instances by his enthusiasm, and a kind of superstition allied to the study of this art or science, pronounced that those eyes generally termed black, frequently denoted health, firmness, courage, and honour; but the grey, deceit and instability. Those objections, we should presume, are only made for the sake of showing a difference of opinion, if they are considered relative:—thus far probability at least accompanies the physiognomist's remarks; the commentator adding, "It is, however, impossible to subscribe to his assertion that all short-sighted persons are deceitful and crafty, or that those who squint have similar propensities to evil: with this learned gentleman we fully coincide, when he alleges, that it is evident both peculiarities alluded to, may be consequences of injury, either of natural defect or accidental violence, and are never found in people whose organs of vision are perfect; indeed many instances might be cited of the actual and known cause of squinting and nearsight, which frequently occur in adults from extreme anxiety and disease."

Small eyes, situated deep in the sockets, are said by Paracelsus to indicate active wickedness, with a mind calculated to oppose with vigour, and suffer with perseverence; and their opposites, very large and prominent eyes, he conceived explained the avaricious and covetous propensities of their possessors: those in constant motion denote fear and care; winking is the mark of foresight, of an amorous disposition, when it does not proceed from the weakness of the organ, and the eye fearful of looking forward, decides upon innate modesty.

Lavater thought blue eyes, in general, signified effeminacy and weakness; yet he acknowledged that many eminent men have blue eyes; still he was convinced that strength and manhood belong more particularly to brown: in opposition to this, the Chinese are known to be an effeminate race of people, yet they rarely have blue eyes. These contradictions, it must be confessed, weaken the reliance we are inclined to place upon appearances during the quiescent state of the eyes, and the indications of their colour. Men intemperate, in anger, and easily irritated, may be found with eyes of all the usual colours; when they incline to green—ardour, spirit, and courage, are their usual attendants. People of a phlegmatic habit, but who may be roused to activity, have clear blue

eyes, which never belong to those inclined to melancholy; and rarely belong to the choleric. Benevolence, tenderness, timidity and weakness are exhibited by the perfectly semicircular arch formed by the underpart of the upper eyelid. Persons of acute and solid understanding have generous open eyes, composing an acute angle with the nose; and when the eyelid forms a horizontal line over the pupil, it is a strong indication that he who possesses it is subtle, shrewd, and penetrating. Wide opening lids showing the white of the ball under the other colours, may be observed in phlegmatic and timid, as well as in the courageous and rash; but in comparing these marks in the characters just mentioned, a very perceptible difference is discovered, the latter is more oblique, better shaped and more firm.

The Eyebrows.—The eyebrows are essential in the expression of the eyes; in anger they are brought down and contracted; in all pleasant sensations, and in astonishment, they assume a fine arch; in youth they are naturally and regularly arched; the horizontal and rectilinear eyebrows belong to the masculine bias of the soul, and when combined with the above designations, show strength of understanding, united with feminine kindness. Those that are deranged in their appearance, with the hair growing in various directions, demonstrate a wild and unsettled state of mind; but if the hair be fine and soft, they signify a gentle ardour. The compressed eyebrow, formed of parallel hairs, is a certain proof of profound wisdom, true perception, and a manly habit of thought. There are eyebrows which meet across the nose; this circumstance gives the person an air of ferocious gloom, which is admired by the Arabs; but the ancients versed in physiognomy conceived such to be the character of cunning: Lavater, on the contrary, discovered them in the most open and worthy countenances, admitting, at the same time, they may indicate a heart ill at ease. Those who think profoundly, and those equally prudent and firm in their conduct, have never high and weak eyebrows, but in some measure equally dividing the forehead, they betray rather debility and apathy; and though men with an opposite character may be found with them, they invariably signify a diminution of the powers of the mind. Thick angular eyebrows interrupted in their lengths, signify spirit and activity; and when they approach the

eyelids closely, the more firm, vigorous, and decided is the character: the reverse shows a volatile and less enterprising disposition; when the extremes are remote from each other, the sensations of the possessor are sudden and violent. White eyebrows are demonstrative of weakness, in the same degree as the dark brows are of firmness.

Lavater considers the nose as the abutment of the forehead, the seat of the brain, without which the face would present a miserable appearance, indeed, an ugly or disagreeable set of features are never accompanied by a handsome nose; but there are thousands of fine and expressive eyes, where a perfectly formed nose is wanting. He describes the proportions of the face as requiring the following particulars. "Its length (that of the nose) should equal the length of the forehead; at the top should begin the indenting; viewed in front the back should be broad, and nearly parallel, yet above the centre somewhat broader; the bottom, or end of the nose should be neither hard nor fleshy, and its under outline must be remarkably definite, well delineated, and neither pointed nor very broad; the sides, seen in front, must be well defined, and the descending nostrils gently shortened; viewed in profile, the bottom of the nose should not have more than one-third of its length; the nostrils must be pointed below, round, and have, in general, a gentle curve, and be divided into equal parts by the profile of the upper lip; the side or arch of the nose must be a kind of oval above, it must close well with the arch of the eye-bone, and near the eye must be, at least, half an inch in breadth. Such a nose is of more worth than a kingdom." Numbers of great and excellent men have flourished in all ages of the world, whose noses would suffer much by Lavater's description of a nose, more valuable to the professor than the wealth of an empire: indeed he is compelled to acknowledge this indisputable fact, and observes that he has seen persons endowed with purity of mind, noble in their conceptions, and capable of exertion, whose noses were very small, and the arches of their profiles inverted; and yet, true to his principles, he discovered, or imagined he discovered, their worth to consist in the elegant effusions of their imaginations, their learning, or fortitude in suffering; and this is accompanied with a proviso, that the remainder of their form must be correctly organized.—

We must submit with deference, that the physiognomist did not present the above as an essential nasal pattern to any set of features, he only fancifully drew a picture of what he thought would be a perfect nose.

Noses arched under the forehead belong to those who possess the energy to command, are capable of ruling, acting, overcoming, or destroying others; rectilinear are the medium between the extremes above noticed, and are appropriated by nature to those who act and suffer with equal power and patience.

Socrates, Larresse, and Boerhave were celebrated men, and it is generally well-known that they had ill-shaped noses; yet they were distinguished for meekness and gentleness. Were it possible to attribute a universal prevalence of disposition to a general form of the nose, individuals of every nation would be found who resemble the Tartars, who have flat and indented noses; the Negroes, who have broad; the Jews, who have high arched noses: in their propensities it would follow, that whatever qualities the physiognomist may apply to those individuals, must also belong to the whole people whose noses bear a resemblance to them.

Mouth.—The admirers of physiognomy attribute great powers to the mouth in expressing the emanations of the mind; and Lavater expatiates upon it with enthusiasm. He says. "Whoever internally feels the worth of the mouth, so inseparable, so well defined, so simple yet so various; whoever, I say, feels this worth will speak and act with divine wisdom." He then proceeds to call it "the chief seat of wisdom and folly, power and debility, virtue and vice, the seat of all love, all hatred, all sincerity, all falsehood, all humility, all pride, all dissimulation, and all truth." Allowing the reverend author full credit for these observations on the mouth, it becomes the duty of every man to notice the physiognomy of that organ; for which purpose it will be requisite to examine the lips separately, to ascertain when they are closed, during the moments of tranquillity, whether that operation was performed without a forcible exertion of the muscles, particularly of the middle of the upper and under lips, the bottom of the middle line at each end, and finally the extent of the middle line on both sides. The character of the man is proclaimed in the lips, the

more firm the latter the more fixed the former; the weak and irresolute man has weak lips, with rapidity in their motion; the vicious, cringing, mean and vile, has a countenance with lips and other members of the face, never well formed or justly proportioned to the other parts of his visage, and the line of which is equally serpentine on either side.

A mouth, the lips whereof are so thin as to present at first view little more than a line, is a prognostic of apathy, yet quiet, and very industrious when pushed. When this description of mouth is raised at the extremities, vanity, affectation, and most probably deliberate malice, distinguish those so formed. The opposites of this kind, are those lips swelled into a considerable size, which denote indolence and sensuality. Lips closed accurately without exertion, and handsome in the outline, belong to the exercise of discretion and firmness. The under lip, hollowed in the middle, denotes a fanciful character.

The mouth naturally closed, invariably signifies fortitude and courage. While the latter quality is in agitation the mouth closes insensibly. The naturally open mouth marks a disposition to complain; the closed on the contrary signifies endurance.

Chin.—The chin when prominent is said to denote something decided; and the receding, the reverse. When the chin is pointed, the possessor is supposed to be penetrating and cunning. Flatness of chin speaks the cold and dry: smallness, fear; and roundness, with a dimple, benevolence.

We have interspersed our remarks with extracts from the expensive work of Lavater, on physiognomy, in order to enable our readers to judge for themselves. The science we believe to be founded in nature; but in justice to ourselves, we cannot suffer those extracts to go forth in this volume, without observing that we believe with much truth and sagacious remarks, there is also a great deal of extraneous matter.

CRANIOLOGY.

We come now to the second subject proposed, which assumes its name from the object it examines, and is the doctrine of Dr. GALL upon the *cranium* or skull—its mode of formation, structure and peculiarities. That gentleman thinks, from its connexion with the brain, to which it is a covering, it has a decided influence upon the seat of thought, and even upon thoughts themselves, and the general disposition of the mind; and hence becomes susceptible of definition.

This doctrine being of much more recent date than that of physiognomy, has obtained a greater number of supporters; yet it is still in an unsettled state of suspense. With an intention to be serviceable to the interests of science, we subjoin a few particulars of the theory as given by the founder, and hope that they will act as a spur to the mind of the inquiring reader to examine the matter more closely, and settle his own opinion.

The inventor was a physician of considerable practice and much esteem in Vienna: natural history, forming collections of plants, &c. were the distinguishing characteristics of his mind from earliest infancy. He was particularly attentive to the heads of objects, their shape, and utility; and during his studies was in the habit of frequently remarking on the heads of his play-fellows and fellow students, on their moral and intellectual character; and while apparently amusing himself, from various traces of resemblance, he formed his judgment of dispositions. As he approached manhood he fixed on medicine as a profession, and was led by an impulse, which he considered the result of his organization to the habit of observation and comparison. He spent much of his time in collecting skulls of dead objects, as well human as of other animals, for the sake of comparison; he had also the copies of many living skulls taken in gypsum; so that eventually he formed the most extensive and valuable collection of these subjects. Dr. Gall soon discovered that the general inferences he had drawn from these observations would not at all times bear him

out, which compelled him to be more particular in his observations, and he found less inconsistency in subsequent remarks. He likewise discovered considerable anxiety at the first to affix a proper and characteristic name to local organs, when he often found change of local situation necessary. Having after severe study surmounted these and various other obstacles which continually presented themselves in opposition to the progress of any thing which had not been taught in the nursery; among other opponents he had to combat with the power of ignorant priests, and a priest-ridden court, but at length he was permitted to deliver lectures to *foreigners* upon his newly discovered science.

Dr. Gall discovered from the anatomy of the brain, that it is not, as generally considered, a pulpy substance, but that it is of the nature of a membrane, in some places not a line in thickness. He was first led to consider this subject with attention, from a knowledge that the membrane had been repeatedly suffering from *hydrocephalus internus*, where a large collection of water is occasionally collected in the ventricles; and the brain becomes distended to a membrane not of the thickness of a line; also a paralysis of the extremities with other partial affections of that member; yet the intellectual faculties remained unimpaired.

The chief results of his anatomical labours were that the entierty of the medullary of the *cerebrum* and *cerebellum*, consists of nervous fibres, and the whole of the *cortical* substance of *ganglions*, by means of which the nervous fibres are nourished, strengthened, and more intimately connected. That the nerves which constitute the essential part of the *cerebrum* and *cerebellum*, as well as of the spinal marrow, are like blood vessels of two kinds, the excurrent, or diverging, and recurrent or converging, which all arise from the spinal marrow, or terminate in it; consequently, that, the origin of the medullary substance of the cerebrum and cerebellum is derived from the spinal marrow. That the cortical substance is the superficial ganglion of the cerebrum and cerebellum; and that all the excurrent nerves terminate in the outer surface of the cortical substance on which the *pia mater* rests, and all the recurrent nerves take their origin in that place.

In the infancy of any science it certainly behoves the inventor to act with extreme caution of which Dr. Gall appears to have been aware, when he says—"We are not to expect to perceive the already developed faculty of the mind, by mere observations made on the skull; it is the *tendency* only, or *aptitude*, or *possibility of any particular intellectual quality* in any individual that *can be discovered*; and besides, *all the predispositions cannot* be selected, because *many* of the supposed organs *cannot* influence the shape of the bones, in consequence of their *remote situations*." Hence, all the organs, and consequently the predispositions, in both animals and men, are said to be innate and more latent perhaps, with respect to their greater portion.

The functions of the brain are said to be threefold:—first, organic life; second, sensitive life; and third, intellectual life. A particular part of the brain is assigned to each of those functions. It is only in consequence of the size of these hemispheres, and the part appropriated to the last of these functions, that man has the largest brain; and not because the size of the human brain is greater than the rest of the body, as has been supposed, nor on account of the comparative thickness of the nerves, as some people have observed. To prove that the organs of thought are placed in the hemispheres of the brain, those parts are said to be of larger size, and more completely developed in animals of different classes, in proportion to their intellectual faculties; and in man they are most perfect.

The arguments adduced by Dr. Gall, in proof of plurality of organs in the brain, are 1st. The sense of fatigue, arising from the mind being long employed on some specific object of contemplation; that sense of relief it experiences from variety. 2ndly, The various degrees in which the different faculties are possessed by the same individual. And 3rdly, The loss of certain faculties and powers of the mind from disease, or accident, affecting certain parts of the brain; whilst those peculiar to other parts are retained.

The separate organs in the skull of man, and of which Dr. Gall claims the discovery, are twenty-six, which he divides into three classes.

Class I.—Comprehends those by which man is enabled to enter into commerce with the world which surrounds

him. The 1st of which he considers to be the organ of sexual love, at the lower and back part of the head. 2. The organ of parental and filial love, and the animal *storge*, at the upper part of the *occiput*. 3. The organ of friendship and fidelity, between the ear and back of the head. 4. The organ of fighting, a little above and below the ear. 5 The organ of slaughter lies a little before and above the preceding. 6. Address or cunning, before and above the latter. 7. The organ of cupidity, is that of address continued almost to the eyes. 8. Of good-nature, in the centre of the upper part of the forehead. 9. Of mimicry or imitation, at the side of good-nature. 10. Of vain-glory or vanity, at the back of the parietal bone. 11. Of constancy or firmness, in the middle of the top of the skull.

II.—The second class of organs comprehend those by which we are enabled to acquire a more familiar acquaintance with objects known to us by means of the external senses. 12. Aptness to learn and retain things, over the foot of the nose, between the two eyebrows, and above the glabella. 13. Aptness to learn and retain places, fills that half of the eyebrow which is towards the nose. 14. Aptness to recollect persons, (doubtful) at the upper part of the inner side of the orbit. 15. The sense of colour lies in the superciliary arch, on the outside of the organ of taste 16. Aptness to learn and retain music, above and behind the exterior angle of the eye, where it joins the organ of capacity. 17. Aptness to learn and retain numbers, is placed on the outside of the organ of music. 18. Aptness to learn and retain words, at the upper and back part of the orbit. 19. Aptness to learn and retain languages, on the upper and anterior part of the orbit. 20. Mechanic arts, behind the organ of number. 21. Prudence and Circumspection, about the middle or side of the head. 22. Loftiness, at the back of the top of the head.

III.—The third class of organs are those which constitute the peculiar prerogatives and glory of the human race, and which more eminently raise man above the brute creation. They all lie on the crown of the head, or on the forehead. 23. Rhetorical acuteness lies on the middle of the forehead, above the organ of thinking and beneath that of good nature. 24. Metaphysical subtlety, on each side of Rhetorical acuteness. 25. Wit at the outside of

the last mentioned. 26. Theoscrophy, in the centre of the top of the forehead.

We do not intend to enter into a detail of those organs as given by Dr. Gall. We will, however, transcribe the remarks upon some few of them only, from a work of great merit, to furnish a general idea of the proof, and as an illustration on which the theory is established.

The organ of sexual love is placed in the cerebellum. It comprises that part of the occiput which lies near the great occipital hole; and in living subjects is to be judged by the thickness and breadth of the throat and neck. As the sexual passion rises, this part of the brain grows in disproportion to the other parts; but when by castration the purposes of nature in its formation are defeated, it ceases to develope and perfect itself. In those men and animals who have suffered this operation, whilst young, it may be observed the back part of the skull ceases to grow, the neck becomes narrow, and the voice loses its manly vigour.

This remark applies to many species of animals. The stallion and the bull have a more perfectly developed cerebellum, and consequently have a thicker and broader head behind than the gelding or the ox. This is obvious to persons engaged in husbandry and riding horses, who give a preference to those stallions whose ears stand widest apart. The male mule, which has no power of procreation, has a very narrow neck, and the ears stand close together.

Through the whole class of quadrupeds the neck of the male is thicker than that of the female, which Dr. Gall attributes to the longer duration of the sexual appetite in the male.

The organ of aptness to learn and retain places has the following observations made upon it.

This organ is apparent in various birds of passage, as swallows and storks, pigeons, which are letter-carriers, dogs, &c. He relates an anecdote of a dog carried from Vienna to London, that returned to the port, took his passage in a ship in which was a gentleman, who travelled to Mentz, from whence the dog went to Vienna.

In men he says this organ appears to operate variously, but in every case is connected with a disposition to observe the relations of space, and produces a delight and

peculiarability in those occupations which depend upon relations.

The arguments adduced against Dr. Gall's theories are, in our opinion, few, weak, and groundless, which could easily be refuted if our space would permit. But now as it has become more generally known, and many elementary books published at a low price, we would strongly recommend our readers to study for themselves. It assuredly is but fair for every individual to give it a chance, particularly as it can injure no one whilst it is probable it may be beneficial to many.

PROGRESSIVE CONDITION OF MAN.

THIS is a subject of no small importance, and the result of its careful study must afford the highest gratification to a philanthropic mind. We extract the following from Arnott's Physics:—While the inferior races of animals seem to have changed as little in any respect, since the beginning of human record, as the trees and herbs of the thickets which give them shelter, the condition of man has fluctuated, and, on the whole, progressed in a very remarkable manner. The inferior animals were formed by their Creator such, that, within one life or generation, they should attain all the perfection of which their nature was perceptible. Their wants were either immediately provided for—as instanced in the clothing of feathers to birds, and of furs to quadrupeds; or were so few and simple, that the supply was easy to very limited powers—except in a few cases where considerable art was required, as by the bee in making its honey-cell, or by the bird in constructing its beautiful nest, and there, a peculiar aptitude or instinct was bestowed. Thus a crocodile, which issues from its egg in the warm sand, and never sees its parent, becomes as perfect and as knowing as any crocodile that has lived before, or will appear after it. But how different from this is the story

of MAN! He comes into the world the most helpless of living beings, long to continue so; and if deserted by parents at an early age, so that he can learn only what the experience of one life may teach him—as to a few individuals has happened who yet have attained maturity in woods and deserts—he grows up in some respects inferior to the nobler brutes. Now, as regards many regions of the earth, history exhibits the early human inhabitants in states of ignorance and barbarism, not far removed from this lowest possible grade, which civilized men may shudder to contemplate. But these countries, occupied formerly by straggling hordes of miserable savages, who could scarcely defend themselves against the wild beasts that shared the woods with them, and the inclemency of the weather, and the consequences of want and fatigue, and who to each other were often more dangerous than any wild beasts, unceasingly warring among themselves, and destroying each other with every species of savage, and even cannibal cruelty—countries so occupied formerly are now become the abodes of myriads of peaceful, civilized, and friendly men, where the desert and impenetrable forest are changed into cultivated fields, rich gardens, and magnificent cities. It is the strong intellect of man, operating with the facility of language as a means, which has gradually worked this wonderful change. By language fathers communicated their gathered experience and reflections to their children, and these to succeeding children, with new accumulation; and when, after many generations, the precious store had grown until simple memory could retain no more, the arts of writing, and then of printing, arose, making language visible and permanent, and enlarging illimitably the repositories of knowledge. Language thus, at the present moment of the world's existence, may be said to bind the whole human race of uncounted millions into one gigantic rational being, whose memory reaches to the beginnings of written records, and retains imperishably the important events that have occurred; whose judgment, analyzing the treasures of memory, has discovered many of the sublime and unchanging laws of nature, and has built on them all the arts of life, and through them, piercing far into futurity, sees clearly many of the events that are to come; and whose eyes and ears, and observant mind at this moment, in every corner of the earth, are watching

and recording new phenomena, for the purpose of still better comprehending the magnificence and beautiful order of creation, and of more worthily adoring its beneficent Author. But there is a change going on in the world, connected closely with the progress of science, yet distinct from it, and more important than half of the scientific discoveries—it is the *diffusion of existing knowledge* among the mass of mankind. Formerly knowledge was shut up in convents and universities, and in books written in the dead languages—or in books which, if in the living languages, were so abstruse and artificial, that only a few persons had access to their meaning; and thus, considering the human race as one great intellectual creature, a small fraction only of its intellect was allowed to come into contact with science, and therefore into activity; which fraction, moreover, was only half-exerted, because sufficient motive was wanting. The progress of science in those times was correspondingly slow, and the evils of general ignorance prevailed.—Now, however, the strong barriers which confined the stores of wisdom have been thrown down, and a flood overspreads the earth; old establishments are adapting themselves to the spirit of the age; new establishments are arising; the inferior schools are introducing improved systems of instruction; and good books are rendering every man's fireside a school. From all these causes there is growing up an *enlightened public opinion*, which quickens and directs the art of every progress and science, and through the medium of a free press, although overlooked by many, is more rapidly becoming the governing influence in all the affairs of man. In Great Britain, partly, perhaps, as a consequence of its insular situation, which lessened among its inhabitants the dread of hostile invasion, and sooner formed them into a united and compact people, the progress of enlightened opinion has been more decided than in any other state."

We do not think many will be found bold enough to contradict the foregoing statement; but we are of opinion that the author has overlooked the most important cause of that great improvement—a cheap press. This must be evident to every one who considers the great number of cheap periodicals that are weekly issuing from the press in this country, containing information on every subject calculated to improve the minds of all classes of the com-

munity; and the avidity with which these are purchased is a certain indication that the labour of the projectors is not lost. As an example of this we shall mention one of these (we believe *the first*) cheap periodicals we allude to "Chambers' Edinburgh Journal," which is familiar to every individual in Great Britain. The first number of this journal appeared in the beginning of the year 1832, at the low price of three half-pence, containing a variety of useful and entertaining matter, equal in quality as well as quantity to what could previously have been obtained for one shilling This first attempt to introduce cheap information was so well appreciated by the public, that of the first number no fewer than from 16,000 to 17,000 copies were sold, and as the work became more generally known, each succeeding number increased its circulation till the average sale amounted to 70,000 or 80,000 copies weekly. This publication has now existed for upwards of sixteen years, and still maintains its popularity This is only one example from many that could be adduced of the success which has attended other equally cheap and valuable periodicals of the present day But it is not alone to periodicals that the labour of the cheap press is confined, and if any example of this is necessary, the reader has only to look at the present volume in his hand, and put the question to himself. "What would the Panorama of Science have cost me a few years ago?" and the answer would certainly be "at least six times its present price!" In conclusion, therefore, it is hoped that this volume will be found to have at least assisted in the Progressive Improvement of Man.

FINIS.

D. Sullivan, Printer, Dublin.